United States Court of Appeals

for the Second Circuit

EXHIBITS

B

75-7362

United States Court of Appeals
FOR THE SECOND CIRCUIT

Docket No. 75-7362

PERMA RESEARCH & DEVELOPMENT COMPANY,

Plaintiff-Appellee,

—v.—

THE SINGER COMPANY,

Defendant-Appellant.

ON APPEAL FROM THE UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF NEW YORK

UNITED STATES COURT OF APPEALS
FILED
DEC 29 1975
A. DANIEL FUSARO, CLERK
SECOND CIRCUIT

EXHIBIT BINDER

VOLUME II (Pages E-454 through E-904)
DESIGNATED PLAINTIFF'S EXHIBITS (59-155)

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12	1964 Ford Test Results	E-1040
20	Letter from L. H. Nagler of American Motors Corporation to Roger Levesque, dated June 26, 1964	E-1042
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36	Two Field Reports: 1) From Roger Levesque and Tom Perrino to F. A. Perrino, R. D. Mainelli and J. Krawczyk. Installation of Steel Drive Gears in Connecticut State Police Cruisers. Westport Barracks and Bethany Barracks. 2) From Tom Perrino to F. Perrino, R. Mainelli, J. Krawczyk and L. Dienes. Connecticut State Police - Westport Barracks, c/o Safety Service Corp. Replacement of Plastic Speedometer Gear with Steel Replacement Gear, dated July, 1964	E-1046
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102	Letter from J. Gomes to R. A. Kloby, dated July 23, 1964	E-1067
111	Memorandum from A. Romel to C. W. Broeker re: "Gear Boxes" for Perma Anti-Skid Units, dated Oct. 26, 1964	E-1068
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115	Memorandum from A. Romel to C. W. Broeker re: Summary of Gear Box Test Results, dated Nov. 24, 1964	E-1076
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191	Letter from Cecil S. Morris to S. J. Murphy re: Attached Report Outlining Singer's Position Under Manufacturing Licensing Agreement with Perma Research and Development Company, dated Oct. 21, 1964	E-1083
195 (pages 1-4)	Letter from S. Karp to Robert Patten of The Singer Company re: Estimated Budget Projection, dated Nov. 30, 1964	E-1093
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380	Letter from S. Karp to R. R. Patten re: Need to Replace Units Installed on Consumers', Stockholders' and Dealers' Cars, dated Dec. 28, 1964	E-1155
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479	Organization Announcement from D. P. Kircher, President of Singer, Announcing the Establishment of a New Operating Division to Bring Together Most of the U.S. Units Primarily Concerned with Consumer Products, dated June 25, 1965	E-1170
487	Memorandum from B. C. Person to A. di Scipio re: Attached Study Plan for the Anti-Skid Control Prepared for the Use of the Study Team, dated July 26, 1965	E-1173
502	Letter from R. A. Wolf, Head, Transportation Research Dept. of Cornell Aeronautical Laboratory, Inc., to B. C. Person re: Suggestion for a Three-phase Program of Research, dated Sept. 1, 1965	E-1178
529	Letter from R. A. Kloby to B. C. Person re: Attached Engineering Evaluation of the Latest Modifications Submitted by Perma to Provide a "Fail-Safe" Feature in the Anti-Skid Control Unit, dated Nov. 16, 1965	E-1180
529A	"Fail-Safe Analysis of Piston and Check Valve Modification", dated Nov. 10, 1965	E-1195
530	Memorandum from the Perma Anti-Skid Control Task Force to A. di Scipio re: Recommended Course of Action for the Perma Anti-Skid Control Program, dated Nov. 18, 1965	E-1196
577 (excluding appendices)	Booklet Entitled "Technical Status Report - Perma Anti-Skid Device", dated July 22, 1965	E-1202
595	Investment and Expenditures for Perma Anti-Skid Device	E-1227
603	Letter from R. A. Kloby to B. C. Person re: Perma Program Inventory Attachments, dated Oct. 20, 1965	E-1228
618	Cancelled Singer Check in the Amount of $85,000.00 to the Order of Monitor Enterprises, Inc., dated Sept. 1, 1965	E-1230
653 (Cover, p.7 "Advanced Control Concepts" thru p.11 to "Adaptive Steering")	SAE Document #690260, "Technological Development Directing the Path to Fully Automatic Vehicle Control Systems", by S. I. MacDuff, J. G. Rivard, E. J. McGlinn	E-1231
655	SAE Document #710248, "The Chrysler 'Sure-Brake' - The First Four-Wheel Anti-Skid System", J. W. Douglas, T. C. Schafer	E-1237

Defendant's Exhibit No.	Description of Document	Exhibit Binder Page
656	Executed Copy of Technical Services Contract Between Perma Research and Development Company and The Singer Company, dated Dec. 21, 1964, With Cover Letter from F. A. Perrino, dated Dec. 21, 1964	E-1248
670	Due to Its Excessive Size, by Stipulation Dated Aug. 7, 1975, DX 670 (Blueprint of Vacuum Container DC 17-342066-900X) is in the Possession of Counsel for Defendant. DX 670 Will be Produced for the Court's Inspection Upon Request.	E-1253
686	"Perma Anti-Skid Detail of Start-Up Manufacturing Expenses July 1 - Dec. 31, 1964"	E-1254
687	Employee History and Compensation Records (Top Page: Albert E. Romel)	E-1256
688 (p. 909 thru p. 910 to "Measurement Methods")	Article on Measurement of Tire Brake Force Characteristics as Related to Wheel Slip (Antilock) Control System Design by J. L. Harned, L. E. Johnston and G. Scharpf	E-1270
689 (p. 298 "Abstract", p. 299 "Braking and Safety" thru p. 306, p. 317 "Automatic Regulation Devices" thru p. 318)	Article on Automatic Brake Proportioning Devices by Guiseppe Puleo	E-1272
700 (at 1, 123-124)	1973 Edition of Ford Brochure Entitled "Car Buying Made Easier"	E-1283
708 (cover, pp. 1, 13, 15, 22, 27, 31, 34, 35, 40, 44)	Modified Plaintiff's Exhibit 129	E-1287

III. Defendant's Exhibits Offered In Evidence At Trial And Rejected

13 (id)	Engineering Appraisal of "Perma" Anti-Skid Device, dated April 9, 1964	E-1298
335 (id)	Memorandum from B. C. Person to S. Boriss, C. W. Broeker and R. H. Elman re: Discussions of Messrs. Romel and Person with Kelsey-Hayes, with Attachments, dated Feb. 15, 1966	E-1302
337 (id)	Engineering Reports from The Ford Motor Company to A. E. Samson of Ford re: The Effectiveness of the Anti-Skid Control Unit as Evaluated by Ford	E-1311

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510 (id)	Memorandum from J. A. Lundin to J. W. Momberg of Singer re: Meeting at Denville Research Laboratory on Sept. 30, 1965	E-1326
559 (id)	Memorandum from A. Romel to B. C. Person re: Trip Report to Ford Motor Company, dated Feb. 17, 1966	E-1331
560 (id)	Letter from B. C. Person to C. F. Bruder re: Information Reviewed with D. P. Kircher of Singer, dated Feb. 25, 1966	E-1336
658 (id)	Letter from S. Linderman to P. DeRensis re: Plaintiff Counsel's Request for Perma Device - First Unit Delivered, dated May 16, 1973	E-1339
659 (id)	Letter from S. Linderman to P. DeRensis re: Plaintiff Counsel's Request for Perma Device - Second Unit Delivered, dated May 22, 1973	E-1340
684 (id)	Letter from H. J. Policinski, Patent Attorney for Kelsey-Hayes Co., to J. K. Lagemann re: Every's Testimony, dated June 6, 1974	E-1341

IV. Court's Exhibits

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1	Letter of P. R. Grand to J. K. Lagemann, dated Nov. 30, 1973	E-1343
5, p. 6 (p. 1 of Ex. A to Ct.'s Exhibit 5)	Portion of Partially Executed Stipulation of Facts	E-1345
6	Fully Executed Stipulation of Facts, dated June 24, 1974	E-1347

PLAINTIFF'S EXHIBIT 59

[PX 59, p 1]

PLTF EXH 78-A
FOR IDEN DATE 3/nh/
LAWRENCE GREENBERG

SINGER

30 ROCKEFELLER PLAZA • NEW YORK 20, N.Y.

MEMORANDUM

TO: Mr. D. P. Kircher

FROM: L. E. Keogh

REFER TO:

DATE: December 11, 1964

SUBJECT:

Per your request of December 9th, I am submitting herewith a brief summary report of the Penna Anti-Skid Control relationship with the Elizabeth Factory.

It is hoped that you will favorably consider endorsing this program so that we may proceed to put it into effect with a minimum of delay.

L. E. Keogh

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FERMA ANTI-SKID CONTROL DEVICE

On June 18, 1964 Elizabeth entered into a two year licensing agreement with Ferma Research and Development Corporation of North Attleboro, Massachusetts, for the exclusive manufacturing rights to the Ferma Anti-Skid Control Device.

Under this agreement Ferma was to act as the marketing entity. Inventory of components from previous manufacturers that was brought into Elizabeth along with the additional components that had been supplied by vendors since the above date amounted to $575,000.

Under this agreement, Elizabeth further assumed certain purchase orders for components required in the fabrication of 50,000 static kits and a somewhat larger number of variable kits and adapters which, including the above inventory, amounted to approximately $1,300,000.

While this commitment contained an element of risk, the merits of the product, market and profit potential seemed to justify this risk.

Because of quality problems encountered in parts supplied by outside vendors and a design deficiency in a gear box, only 500 units were made and shipped to Ferma between June and October.

Ferma depended on receipt of the product and lack thereof prevented any cash flow, so that Ferma's financial condition became hazardous to the point that bankruptcy appeared as a possibility.

Ferma then offered to sell to Elizabeth all its patents, patent applications and trademarks, along with all the marketing rights for the sale of the product in the United States and Canada in return for Singer's assumption of certain liabilities on a loan basis and the payment of a royalty on the sale of the product, based on a percentage of the factory invoice price.

[PX 59, p 2]

At this point Singer was faced with a two-fold choice:

1. To improve its profit potential by controlling the product and its market through ownership of its patents, at the same time protecting its investment.

2. Remain as a sub-contractor to Perma, should they (Perma) be able to secure additional financing to carry through over the period of market expansion.

It is recommended to make the first choice and Exhibit A is a final draft of the agreement as negotiated with Perma.

EXHIBIT A (Salient Points)

Singer to buy patents, patent application, trademarks and all rights in the United States and Canada on the Anti-Skid Device.

All Perne's tooling is included in this sale.

1. In return for the above, Singer gives to Perne $24,000.
2. Singer assumes certain of these liabilities amounting to $210,000.
3. Payment to be made by virtue of royalties.

Royalty schedule:

First 21,000 units — no royalty (Elizabeth amortizing loan at the rate of $1.0. per unit)

Next 15,000 units — no royalty (Elizabeth amortizing a $24,000 advance royalty payment at $1.50 each)

Royalty payments on shipments for next five years equal to 10% of factory invoice price.

Royalty drops to 5% factory invoice price for next five years.

In event of O.E.M. sales, royalties will be 5%, factory invoice price of 25% of royalty payment if O.E.M. Account to do their own manufacturing.

Royalties cease in the event of development of a competing product that infringes any area for patent claim.

Marketing:

Perma's approach to the marketing of this device was to sign up distributors in the various parts of the country with the prime objective of generating immediate cash flow by filling the pipe lines of a large number of regional distributors.

One of the regional distributors - Monitor Enterprises, had conducted discussions with Elizabeth during the early association with Perma and it was quite clearly indicated that their approach to the market was on a more professional basis than that of Perma. Lacking the necessary manpower at Elizabeth to conduct marketing, and in view of the time element and need to get the product moving and money coming in, it is recommended that Monitor Enterprises be appointed as exclusive U.S. distributor.

Number 1 - Agreement with Monitor.

Salient features of the agreement between Singer and Monitor for National Distributing Rights:-

1. Monitor guarantees to take 50,000 units in the first twelve month period from date of signing to be delivered at a prescribed schedule.
2. Monitor to spend minimum $250,000 each year towards promotion and advertising. This does not include salesmen's salaries, overhead, training, etc.
3. Units would be sold by Elizabeth to Monitor at $31.00 per unit, including $3.00 Federal Excise Tax.
4. Renewal option end of first year guarantees 100,000 units, prices to be negotiated.

EXHIBITS C and D

C Pro Forma Income Statement

D Summary of Flow of Perma Purchased Inventory

[illegible]

PRO-FORMA INCOME STATEMENT

		1965		1966		1967
		50,000		100,000		200,000
Sales	($1.00)	2,550,000	($48.50)	4,850,000	($48.50)	9,700,000
Fed. Ex. Tax @ 8%		188,300		359,300		710,600
		2,361,100		4,490,700		8,981,400
Net Sales		1,517,500	($27.30)	2,730,000	($26.00)	5,200,000
Std. Cost($50,000 @30.35)						
Std. Gross Margin		843,600		1,760,700		3,781,400
Additional Costs						
		795,500	(10% N.S.)	949,070	(10% N.S.)	898,140
Royalties ($50,000 @5.91)		87,000				
Repair & Rework-Gear Box ($50,000 @1.74)		44,000				
Add'l. Ops.-Sensing Unit ($50,000 @ .88)						
		20,000	(.20)	20,000	(.10)	20,000
Marketing Costs ($50,000 @$.40)		125,000	(1.25)	125,000	(.625)	125,000
Tech. Services ($50,000 @$2.50)		50,000				
Start Up Costs ($50,000 @$1.00)		[illegible]		949,070		1,043,140
Total Additional Costs						
Income - Pre-Tax		722,100*		1,760,630		2,738,260

* ADDITIONAL SALES TO ST. JOHNS $30,000 INCOME PRE-TAX

E-460

[PX 59, p 7]

[PX 59, p 7]

Inventory of Components purchased from various Ferma contacts as a part of the original take-over of the Ferma operation should be completely exhausted by the end of 1955 assuming sales of 50,000 finished units and 12,000 sets of parts to St. Johns.

Total value of inventory to be purchased will amount to $1,527,000.

In addition to the above inventory to be purchased from Ferma contacts, it will be necessary to purchase additional components at a value of $146,000 in order to complete the 62,000 sets of parts which will be used in 1955.

UNIT COST

	1955	1956	1957
Material	$ 27.15	$ 24.45	$ 23.25
Labor	.30	2.85	2.75
Overhead (All)	2.90	—	—
Total	$ 30.35	$ 27.30	$ 26.00

[PX 60A, p 1]

PLAINTIFF'S EXHIBIT 60A

EXHIBIT A

AGREEMENT dated the 21st day of December, 1964, by and between THE SINGER COMPANY ("Buyer"), a New Jersey corporation, with principal offices at 30 Rockefeller Plaza, New York, New York, and PERMA RESEARCH AND DEVELOPMENT COMPANY ("Seller"), a Delaware corporation, with principal offices at 345 East Washington Street, North Attleboro, Massachusetts.

W I T N E S S E T H :

1. (a) Sale and Transfer of Assets. Seller will sell, transfer, assign and convey to Buyer at the closing provided for in Section 2 hereof (the "Closing") the following assets:

(i) All of its inventions in any way relating to or useful in the manufacture of the "Perma Anti-Skid Control" presently being manufactured by Buyer for Seller, pursuant to an agreement between Buyer and Seller dated June 18, 1964, together with all United States and Canadian patents and patent applications relating thereto, except for U.S. patent application SN 203,075 filed June 18, 1962, a license under which Seller hereby grants to Buyer pursuant to Section 1(f) hereof. Such "Perma Anti-Skid Control" and any improvement or modification thereof (so long as any portion of such "Perma Anti-Skid Control" or such "Perma Anti-Skid Control" as so improved or modified comes within any claims of any U.S. patent or pending U.S. application assigned or to be assigned hereunder during the life of any such patent or the pendency of any such application) shall hereinafter be referred to as the "Product". Without limiting the generality of the foregoing,

Seller agrees to assign to buyer the following patent and patent applications:

Patent

U.S. No. 2,881,879 issued April 14, 1959

Canadian No. 657042 issued February 5, 1963

" " 657041 " " " "

Patent Applications

U.S. SN 322,716 filed November 1963 (and continuation in part filed November 2, 1964).

Canadian SN corresponding to such continuation in part of U.S. SN 322,716.

(ii) All of Seller's interest, if any, in the tools and equipment listed on Schedule A. attached hereto.

(iii) Seller's U.S. and Canadian rights in the trademark or tradename "Perma", "Perma Anti-Skid Control" and any variant or variants thereof. Seller may continue to do business under its corporate name but shall not feature such corporate name in connection with any automotive product or any part or subassembly of the Product.

(b) Consideration for Sale and Transfer. Subject to the terms and upon satisfaction prior to or at the closing of the conditions set forth in Section 5 hereof and in reliance on the representations and warranties of Seller herein contained, and in consideration of such sale, conveyance, transfer and delivery, Buyer agrees to:

(i) pay royalties to Seller in accordance with Section 3 hereof;

(ii) deliver to Seller at the Closing an undertaking in the form of Exhibit 1 hereto.

(iii) deliver to Seller at the Closing its check for $24,000.

(c) Instruments of Conveyance and Transfer. Seller agrees to deliver to Buyer at the Closing bills of

sale, assignments and such other good and sufficient instruments of conveyance and transfer, in form satisfactory to Buyer's counsel, Messrs. Winthrop, Stimson, Putnam & Roberts, as shall be effective to vest in Buyer good and marketable title to the assets to be sold, conveyed, transferred and delivered hereunder.

(d) Further Assurances. From time to time after the Closing, at Buyer's request and without further consideration, Seller agrees to execute and deliver at its expense such other instruments of conveyance and transfer and take such other action as Buyer reasonably may require more effectively to convey, transfer to and vest in Buyer all of its right, title and interest in and to any property to be sold, conveyed, transferred and delivered hereunder, and to give Buyer the same right of use and possession thereof as Seller has or purports to have.

(e) Seller's Note. Seller shall deliver to Buyer at and/or after the Closing its note or notes in the form of Exhibit 2 hereto in the principal amount or amounts of the "Liabilities" of Seller assumed by Buyer pursuant to Exhibit 1 hereto. Such note or notes shall be adjusted or surrendered by Buyer as royalties are earned pursuant to Section 3(c)(i)(B) below.

(f) License. Seller hereby grants Buyer an irrevocable, non-exclusive, royalty-free license to make, use and sell for use in connection with the Product, with right to sublicense, from the Closing under Seller's U. S. patent application SN 203,075 filed June 18, 1962, any patent issued thereunder and under any Canadian patent application or patent containing similar claims hereafter filed or issued, and under any improvement or modification of any of the foregoing.

(c) Seller shall forthwith assign to Buyer, without additional consideration, all U.S. and Canadian rights in inventions, U.S. and Canadian patents and patent applications and U.S. and Canadian rights in improvements of any nature whatsoever relating to the Product or the design and manufacture thereof developed by or coming into the possession of Seller or any employee of Seller during the period of time Buyer is obligated to pay royalties to Seller pursuant to Section 3 hereof.

2. Closing. The Closing of the transactions provided for in Section 1 will take place at the offices of Buyer's counsel, Winthrop, Stimson, Putnam & Roberts, 30 Rockefeller Plaza, New York 20, New York, at 12 o'clock noon on December ( ), 1964. If due to causes beyond the control of either Buyer or Seller the Closing is not consummated on said date or within thirty (30) days thereafter, this Agreement shall terminate without liability of any kind on the part of Buyer or Seller.

3. Royalties.

(a) Definitions. The following terms shall have the following meanings when used herein:

"factory invoice price" means invoice price less (to the extent included in such invoice price) Federal excise tax, sales tax, discounts and shipping costs.

"original equipment manufacturer" means a manufacturer of automobiles, trucks, farm equipment, and any other motor vehicle making and/or installing a Product upon any such vehicle.

(b) Payment of Royalties. Royalties hereunder shall be payable by Buyer to Seller by the twentieth day of each of the months of January, April, July and October on sales and use of the Product for which payment has

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been received by Buyer, less returns, during the previous calendar quarter from its purchaser or licensee. Such payment to Seller shall be accompanied by a satisfactory reconciliation statement which shall also reconcile royalties earned and applied against advance royalties or loans hereunder.

(c) Rates. (i) Buyer shall subject to subsection (c) hereof pay royalties to Seller on sales of the Product in the United States and Canada by Buyer or Buyer's manufacturing licensees after the Closing except sales to original equipment manufacturers as follows:

A. None on the first 16,000 units of the Product sold;

B. On the first 20,200 units of the Product sold in the United States and/or Canada after the first 16,000 units sold, $10 per unit, which royalty as earned shall be applied by Buyer only to the repayment by Seller of Buyer's loan to Seller pursuant to Section 1(b)(ii);

C. After sale of the Product provided for in B above, 10% of the factory invoice price for a period of five years;

D. After expiration of the period referred to in C above, 5% of the factory invoice price for an additional period of five years;

E. No royalty shall be payable to Seller on any sales of the Product to a manufacturing licensee of Buyer for resale.

(ii) Notwithstanding subsection 3(c)(i)(E) above, Buyer shall pay a royalty to Seller on sales of the Product or components thereof after the Closing by

[PX 60A, p 6]

Buyer or its licensees to original equipment manufacturers in the United States and Canada of 5% of the factory invoice price for a period of ten years from the Closing; and

(iii) Buyer shall pay a royalty to Seller on the manufacture and use of the Product or components thereof after the Closing by Buyer-licensed original equipment manufacturers or their licensees in the United States and Canada of 25% of the royalties received by Buyer in connection therewith for a period of ten years from the Closing.

(d) Records. Buyer shall keep full and accurate records with respect to sales and use of the Product and royalties received in connection therewith in sufficient detail to enable the royalties payable hereunder to be determined. Any authorized representative of Seller reasonably satisfactory to Buyer shall have the right at any time upon reasonable notice to examine such records and to examine the books, accounts and records of Buyer insofar as they pertain to sales of the Product.

(e) Cessation. In the event that a third party sells in the United States an anti-skid device which substantially comes within the claims of the United States patent assigned in Section 1 hereof or the claims of a United States patent issued to Buyer covering the Product pursuant to said United States application SN 322,716 or its associated continuation in part and such claims are held invalid by a judgment or decree by a court of competent jurisdiction, from whose decision no appeal is taken, Buyer, its licensees and customers will thereafter be released from

[PX 60 A, p 7]

all obligations under this Agreement to pay royalties on sales of the Product in either the United States or Canada. Seller shall have the right at its own expense and with counsel of its own choice satisfactory to Buyer to participate in any action for infringement of such claims brought by Buyer.

4. Representations and Warranties by Seller. Seller represents and warrants that:

(a) Ability to Carry Out Agreement. Seller is not a party to, subject to or bound by any agreement which will remain in effect after the Closing or any judgment, order, writ, injunction or decree of any court or governmental body which could prevent:

(i) the carrying out of this Agreement;

(ii) the use of any assets to be conveyed hereunder; or

(iii) the manufacture or sale of, or the right to manufacture and sell, the Product.

(b) Authorization and Approval of Agreement. At the Closing the execution, delivery and performance of this Agreement by Seller will have been duly and effectively authorized by all requisite corporation action, including all requisit approval of Seller's stockholders.

(c) Title to Assets. At the Closing Seller will have good and marketable title to all of its assets (including patent and patent applications) to be sold and

[PX 60A , p 8]

transferred hereunder, free and clear of all liens and encumbrances.

(d) Financial Statements, Schedule and Exhibit. Seller has heretofore furnished Buyer with complete copies of the audited financial statements of Seller for the year ended June 30, 1964, including a balance sheet, a statement of income, expense and deficit and the report of Howard J. Swanson, independent certified public accountant, with respect to such financial statements. All such financial statements have been prepared in accordance with generally accepted accounting principles consistently followed throughout the period indicated, reflect all known liabilities of Seller, including all contingent liabilities, and present fairly the financial condition of Seller at such date and the results of its operations for the period then ended. The information contained in Schedule A hereto is accurate and correct and the liabilities listed in Exhibit 1 hereto constitute all of Seller's accounts payable, debts and sundry liabilities as of November 30, 1964 with the exception of a contingent liability to the Worcester Stamped Metal Company, a Massachusetts corporation, a first mortgage on Seller's plant and real estate in North Attleboro, Massachusetts, in the amount of $15,000.00 and other sundry indebtedness not in excess of $30,000.00.

(e) Disclosure. No representation or warranty by Seller contained in this Agreement and no statement contained in any certificate, list or other instrument furnished or to be furnished to Buyer pursuant hereto or in connection with the transactions contemplated hereby contains or will contain any untrue statement of a material fact, or omits

[PX 60A, p 8]

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[PX 60 A, p 9]

or will omit to state a material fact known to Seller necessary in order to make the statements contained therein not misleading, or necessary in order to provide a prospective purchaser of the assets to be sold hereunder with proper information as to the value of such assets and the Product.

(f) Seller has no right, title or interest in any U. S. or Canadian patent or patent application other than those assigned hereunder any claim of which is infringed by the Product or the manufacture, use or sale thereof.

5. Conditions Precedent to Buyer's Obligations. All obligations of Buyer to be performed at the Closing under this Agreement are subject to the fulfillment of each of the following conditions prior to or at the Closing:

(a) All proceedings taken in connection with the transactions contemplated herein and all instruments and documents required in connection therewith or incident thereto shall be satisfactory in form and substance to Messrs. Winthrop, Stimson, Putnam & Roberts.

(b) The representations and warranties of Seller contained in this Agreement or in any certificate or document delivered to Buyer pursuant hereto shall be deemed to have been made again at the Closing and shall then be true in all material respects; Seller shall have performed and complied with all agreements and conditions required by this Agreement to be performed or complied with by it prior to or at the Closing; and Buyer shall have been furnished with such certificates as Buyer may reasonably request of appropriate officers of Seller, dated the Closing date, certifying in such detail as Buyer may reasonably request to the fulfillment of the foregoing conditions. or omit

[PX 60 A, p 10]

(o) Buyer shall have been furnished with an opinion dated the Closing date of Sullivan & Worcester, counsel for Seller, to the effect that:

(i) Seller is a corporation duly organized, validly existing and in good standing under the laws of the State of Delaware and duly qualified to do business in the Commonwealth of Massachusetts, and to the best of their knowledge and belief, the character of the properties owned by Seller and the nature of the business conducted by it do not require it to qualify to do business in any other state;

(ii) the execution, delivery and performance of this Agreement have been duly authorized by all necessary corporate action, and this Agreement has been duly executed and delivered by Seller and constitutes a legal, valid and binding obligation of Seller;

(iii) to the best of their knowledge and belief, Seller has good and marketable title to the patents and patent applications to be sold hereunder free and clear of all liens and encumbrances;

(iv) to the best of their knowledge and belief after an appropriate investigation, Seller has complete and unrestricted power to make the sale, conveyance, transfer and delivery of its assets to be sold by it as provided in this Agreement;

(v) the instruments of conveyance and transfer executed and delivered by Seller at the Closing are valid in accordance with their terms and are effective to transfer and convey to Buyer all properties and assets owned by Seller and to be transferred hereunder at the Closing, free and clear of all liabilities, obligations, liens and encumbrances;

[PX 60 A, p 11]

(vi) all other actions and proceedings required by law or this Agreement to be taken by Seller at or prior to the Closing in connection with this Agreement and the transactions provided for herein have been duly and validly taken; and

(vii) except as may be specified by said counsel, they do not know of any material litigation, proceeding or governmental investigation pending or threatened against or relating to Seller, its property or business, or the transactions contemplated by this Agreement, or any legal impediment to the continued operation and use in the ordinary course of business of the properties and assets to be transferred hereunder.

(d) Buyer shall have received an opinion dated the Closing date of Messrs. Winthrop, Stimson, Putnam & Roberts, stating that the forms of the instruments of conveyance and transfer referred to in subdivision (v) of the preceding paragraph are satisfactory to it.

(e) Seller and Buyer shall have entered into a technical service contract in the form of Exhibit 3 hereto.

6. Indemnification of Buyer. Seller agrees to defend, indemnify and hold harmless Buyer against and in respect of:

(a) Any and all loss, damage or deficiency resulting from any misrepresentation or breach of warranty by Seller made or contained in this Agreement or in any certificate or document executed and delivered to Buyer under or in connection with this Agreement or the transactions contemplated herein.

(b) Any and all loss, damage or liability re-

[PX 60A, p 11]

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sulting from any infringement of any U.S. or Canadian patent by the Product.

(c) All liabilities and obligations of Seller not assumed by Buyer pursuant to Exhibit 1 hereto.

(d) Any and all actions, suits, proceedings, claims, demands, assessments, judgments, costs and expenses incident to any of the foregoing, provided, however, that if any such action, suit or proceeding shall be commenced against or any such claim, demand or assessment be asserted against Buyer in respect of which Buyer proposes to demand indemnification, Seller shall be notified to that effect with reasonable promptness and shall have the right to assume the entire control of the defense, compromise or settlement thereof, including at its own expense employment of counsel satisfactory to Buyer, and in connection therewith Buyer shall cooperate fully to make available to Seller all pertinent information under its control.

7. Cancellation of Manufacturing Agreement. That certain Agreement dated June 18, 1964 by and between Seller and Buyer shall be deemed null and void and of no force and effect simultaneously with the Closing, and all rights and obligations of the parties thereunder shall then terminate, except Seller's open account indebtedness thereunder to Buyer of $9,042, plus the amounts due Buyer entered on Schedule A to Exhibit 1, which shall survive.

8. License to Seller. Buyer hereby grants Seller an irrevocable, exclusive, royalty-free license with right to sublicense, from the Closing, under U. S. patent No. 2,881,879 to make, use and sell any automobile braking mechanism which operates under the control of an accelerator pedal only.

9. Covenant Not to Compete. Seller shall not, directly or indirectly, compete with Buyer in the manufacture or sale of any device designed to prevent the wheels of a motor vehicle from skidding upon application of the brakes thereof or of any substitute or equivalent products during the period royalties are payable to Seller hereunder.

10. Reversion Right. In the event Buyer does not incur direct and indirect costs of at least $100,000 for marketing, promoting and advertising the Product (including direct promotion and advertising expenses incurred by Buyer's distributors which such distributors are contractually obligated to Buyer to incur) in any calendar year between January 1, 1966 and the December 31st preceding the time of expiration of Buyer's duty to pay royalties hereunder, Seller upon written notice to Buyer within six months of receipt of Buyer's report hereinafter referred to may notify Buyer of its exercise of its rights under this Section. Buyer shall make a report to Seller within 90 days of the end of each calendar year of the marketing, advertising and promotion expenses for which Buyer claims credit under this paragraph. Such report shall set forth in the aggregate such direct and indirect costs incurred by Buyer and such direct costs incurred by Buyer's distributors pursuant to contractual obligation. Buyer may conclusively rely upon advice of such distributors with respect to their incurrence of such direct costs. Buyer within 15 days of receipt of such notice shall assign and convey to Seller the patents and patent application assigned and conveyed hereunder, any other patents or applications held by Buyer the claims of which are infringed by the Product, and all tools of Buyer used by Buyer exclusively for the manufacture

[PX 60 A, p 14]

of the Product in consideration of the payment by Seller of all its debts to Buyer, if any, a cash payment by Seller to Buyer of $50,000 plus the amount by which the book value less amortization of such tools exceeds $35,876 and the assumption by Seller of Buyer's licenses and distributor contracts relating to the Product. Seller shall remove any such tools at Buyer's plant at Seller's expense. If Seller exercises its right hereunder and fails to pay such cash consideration upon tender of assignment of the aforesaid assets, Seller shall have no further rights under this Section. Buyer shall have the right to liquidate any inventory of the Product after such assignment and royalties shall continue to be payable in accordance with Section 3 hereof on such sales. Except for such royalties and a final accounting hereunder, this Agreement shall terminate upon such assignment to Seller under this Section.

11. Access to Information and Documents. Seller will give to Buyer and to Buyer's counsel, accountants, engineers and other representatives full access during normal business hours to all the properties, documents, contracts, commitments and records of Seller and furnish Buyer with copies of such documents (certified if so requested) and such information with respect to the affairs of Seller as Buyer may from time to time reasonably request. All information so furnished will be retained by Buyer in confidence. Seller and Buyer mutually agree that following the Closing each, during the normal business hours, will afford the other, its counsel and accountants, full access to Seller's books, records and other data retained or delivered by Seller pursuant to this Agreement, as Buyer or Seller may reasonably request.

E-475 [PX 60A, p 14]

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application) shall hereinafter be referred to as the "Product". Without limiting the generality of the foregoing,

[PX 60A, p 1]

[PX 60 A, p 15]

12. Commissions and Finder's Fees. Each of the parties represents that the negotiations relative to this Agreement and the transactions contemplated hereby have been carried on by Seller directly with Buyer and in such manner as not to give rise to any valid claims against any of the parties hereto for a brokerage commission, finder's fee or other like payment.

13. Marketing. Buyer in its absolute discretion shall determine the method of manufacturing, exploiting and marketing the Product.

14. Seller Admits Validity. None of Seller, any successor to or assignee of Seller shall challenge the validity or legality of the patent or patent applications assigned hereunder or any patent issued pursuant thereto.

15. Survival of Representations and Warranties. All representations and warranties made by Seller under this Agreement in connection with the transactions contemplated hereby or in any certificate, list or other instrument delivered pursuant hereto shall survive the Closing and any investigation made at any time with respect thereto.

16. Notices. All notices and other communications hereunder shall be in writing and shall be deemed to have been duly given if delivered or mailed, first-class postage prepaid;

(a) If to Seller, 345 East Washington Street, North Attleboro, Massachusetts.

(b) If to Buyer, to The Singer Company, 321 First Street, Elizabeth, New Jersey, Attn: General Manager (with copy to Messrs. Winthrop, Stimson, Putnam & Roberts, 30 Rockefeller Plaza, New York 20, New York).

[PX 60A, p 15]

[PX 60A, p 15]

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(c) Instruments of Conveyance and Transfer. Seller agrees to deliver to Buyer at the Closing bills of

E-463 [PX 60A, p 2]

[PX 60 A, p 16]

Such names and addresses may be changed by written notice.

17. Further Indemnity. Contemporaneously with the execution of this Agreement, Buyer is purchasing from Worcester Stamped Metal Company and/or American Emblem Company, Incorporated 3,110 "sensing units" and "gear boxes" (components of the Product) at $13.85 for each component consisting of one sensing unit and one gear box, which sensing units will require certain re-work. Seller agrees to indemnify and hold harmless Buyer for all re-work costs and expenses incurred by Buyer in connection with each such sensing unit in excess of $1.00 for each such unit. In the event Buyer shall have a claim or claims under this Section, Buyer shall have the right to withhold royalties hereunder to the extent of any such claim or claims.

18. Entire Agreement and Amendments. This Agreement, including the Exhibits and Schedules referred to herein which are a part hereof, contains the entire understanding of the parties hereto with respect to the subject matter contained herein and may be amended only by a written instrument executed by Seller and Buyer or their respective successors or assigns. There are no restrictions, promises, warranties, covenants, or undertakings other than those expressly set forth herein. The section and paragraph headings contained in this Agreement are for reference purposes only and shall not affect in any way the meaning or interpretation of this Agreement.

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of any of the foregoing.

[PX 60A, p 3]

[PX 60 A, p 17]

19. Counterparts. This Agreement may be executed simultaneously in two or more counterparts, each of which shall be deemed an original but all of which together shall constitute one and the same instrument.

20. Parties in Interest. This Agreement shall inure to the benefit of and be binding upon Seller, Buyer and their respective successors and assigns.

21. Applicable Law. This Agreement shall be construed and enforced in accordance with the laws of the State of New York.

IN WITNESS WHEREOF, the parties hereto have duly executed this Agreement as of the date first above written.

THE SINGER COMPANY

Attest:

By _____

PERMA RESEARCH AND DEVELOPMENT COMPANY

Attest:

By _____
President

Agreement

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[PX 60A, p 17]

under shall be payable by Buyer to Seller by the twentieth day of each of the months of January, April, July and October on sales and use of the Product for which payment has

[PX 60A, p 4]

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[PX 60 A, p 18]

SCHEDULE A - PAGE 1

PROPERTY OWNED BY PERMA RESEARCH AND DEVELOPMENT COMPANY

Tooling located at Danielson Manufacturing Company, Danielson, Connecticut

	DESCRIPTION	PART NO.	COST
1	Mold Frame for Adaptor		$1,050.00
1	2 Cav. insert for 1963 Chrysler adaptor	B-3200	775.00
1	2 Cav. insert for Chevrolet adaptor	B-5000	775.00
1	2 Cav. insert for Ford adaptor	B-1100	775.00
1	2 Cav. insert for 1963 Buick adaptor	B-9100	775.00
1	2 Cav. insert for Pontiac adaptor	B-7100-A	775.00
1	2 Cav. insert for Buick Special adaptor	B-9200	775.00
1	Cavity hold for adaptor blanks	#400	550.00
Tooling required for Machined adaptors (from adaptor blank #400)		B-5000-2	100.00
		B-9000-A	100.00
		B-4000-A	100.00
		B-3000-A	100.00
		B-7000-A	100.00
		B-6000-A	100.00
Assembly Fixture for use in producing adaptor			500.00
1	Mold base to cover molds for production of gear series listed below		1,800.00
1	1 Cav. to produce part	AK4P-19T	300.00
1	1 Cav. to produce	AK4P-21T	300.00
1	1 Cav. to produce	AK3F-17T	300.00
1	1 Cav. to produce	AK3F-18T	300.00
1	1 Cav. to produce	AK3F-19T	300.00
1	1 Cav. to produce	AK3F-20T	300.00
1	1 Cav. to produce	AK3FF-18T	150.00
1	1 Cav. to produce	AK3FF-19T	150.00
1	1 Cav. to produce	AK3FF-20T	150.00
1	1 Cav. to produce	AK3FF-21T	300.00
1	1 Cav. to produce	AK4CH-18T	300.00
1	1 Cav. to produce	AK4CH-20T	300.00
1	1 Cav. to produce	AK2A-17T	300.00
1	1 Cav. to produce	AK2A-18T	300.00
1	1 Cav. to produce	AK2A-19T	300.00

[PX 60A, p 18]

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[PX 60 A, p 19]

Tooling located at Danielson Mfg. Company, Continued 2.

1	1 Cav. to produce	AK3FA-17T	300.00
1	1 Cav. to produce	AK3FA-18T	300.00
1	1 Cav. to produce	AK3FA-19T	300.00
1	1 Cav. to produce	AK3FA-20T	300.00
1	1 Cav. to produce	AK3FA-21T	300.00
1	1 Cav. to produce	AK4B-19T	300.00
1	1 Cav. to produce	AK4B-20T	300.00
1	1 Cav. to produce	AK4B-21T	300.00
1	1 Cav. to produce	AK4BS-19T	300.00
1	1 Cav. to produce	AK4BS-20T	300.00
1	Cav. for gear, part	AK1RA-20T	300.00
1	Cav. for gear	AK1R-21T	300.00
1	Cav. for gear	AK4P-18T	300.00
1	Cav. for gear	AK4P-20T	300.00
	Tooling for blank adaptor sleeve & nut		175.00
1	2 Cavity mold complete to produce transmission gear & shaft	#125	1,350.00
	Total		18,925.00

TERMS AND CONDITIONS:

Charges for dies, molds, tools or gauges (hereinafter called "tools") not specifically charged to the customer do not convey ownership and remain company property. Tools paid for by the customer do convey ownership and the right to remove them from the premises of the company upon proper notice and upon payment for engineering services not normally included in the tool charge. These services vary with the technical complexity of each job and average between 25% and 40% of the original tool charge. In those instances where Danco standard mold bases are used, dies only are the property of the customer.

Tools specifically charged to you will be held for your exclusive use and will be kept in good condition for production by us without expense to you, reasonable wear excepted, for a period of time ending three years after completion of last order.

1 1 Cav. to produce

[PX 60 A, p 20]

SKED. A, p 3

Tooling located at Danielson Mfg. Company, continued 3.

Thereafter, payment for such maintenance is the liability of the owner of the molds, subject to voluntary participation by us if economic considerations justify. Charges will be made for repairs necessitated when a tool has outlived its useful li fe.

Insurance is carried on your tools while in our possession covering most risks, including fire, theft, transportation, water damage, etc. This coverage also applies if we send your mold out of our plant for repair or alteration.

SKEL-A. P

[PX 60 A, p 21]

PROPERTY OWNED BY PERMA RESEARCH AND DEVELOPMENT COMPANY

Tooling located at Worcester Stamped Metal Company, Worcester, Mass.

DESCRIPTION	PART NO.	COST
Tooling for Cans		$ 2,600.00
Tooling for Covers		700.00
Tooling for Cover #7146		800.00
Tooling for Dished Plate #7145		350.00
Tooling for Dished Plate #7144		350.00
Tooling for PV-2A-1A 8 & 9		455.92
	TOTAL	$ 5,255.92

TERMS AND CONDITIONS:

In accordance with the Termination Agreement between Perma and Worcester Stamped Metal Company dated June 18, 1964, paragraph number 5 states "Worcester acknowledges and agrees that all molds, tools and dies used in the manufacture by Worcester of parts and components for Perma Anti-Skid Control units are the property of Perma and may be removed by Perma or its nominee with out the payment to Worcester of any further charges of any kind."

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[PX 60 A, p 22]

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PROPERTY OWNED BY PERMA RESEARCH AND DEVELOPMENT COMPANY

Tooling located at Unit Tool Company, Venturi Avenue, Warwick, R. I.

DESCRIPTION	PART NO.	COST
Set of tools for Friction Spring RS-10		$ 250.00
Set of tools for Friction Spring RS-1		135.00
Set of tools for Friction Spring RS-4		135.00
Set of tools for Friction Spring RS-5		65.00
Set of tools for Friction Spring RS-6		1,250.00
Piorcing Tool		200.00
Forming Tool		65.00
Tooling		85.00
	TOTAL	$2,185.00

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SKED A p 6

[PX 60 A, p. 23]

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PROPERTY OWNED BY PERMA RESEARCH AND DEVELOPMENT COMPANY

Tooling located at Merriman Brothers, Amory Street, Boston, Mass.

DESCRIPTION	PART NO.	COST
Tools to produce links in accordance with drawing #104		$ 802.75
Tooling to sinter Governor Weights		1,020.00
	TOTAL	$ 1,822.75

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the Closing, free and clear of all liabilities, obligations, liens and encumbrances;

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SKED. A #7

[PX 60 A, p. 24]

PROPERTY OWNED BY PERMA RESEARCH AND DEVELOPMENT COMPANY

Tooling located at Peerless Engineering Company, Providence, Rhode Island

DESCRIPTION	PART NO.	COST
Tools for PV-1 Body		$ 85.00
Tools for PV-2 Valve Piston		25.00
Tools for PV-3 Flange Nut		60.00
Tools for PV-4 Piston Nut		25.00
Tools for PV-5 Piston Stop		25.00
		$220.00

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[PX 60 A, p. 25]

SKED A p 8

PROPERTY OWNED BY PERMA RESEARCH AND DEVELOPMENT COMPANY

Tooling located at Dixson Sintaloy Company, Stamford, Connecticut

DESCRIPTION	PART NO.	COST
Set of Tools for Spider		$ 1,460.00
Tooling to Sinter Gear and Can for Anti-Skid		4,322.50
Tooling for Gear Box Coupling		685.00
	TOTAL	$ 6,467.50

braking mechanism which operates under the control of an accelerator pedal only. E-473 [PX 60A, p 12]

[PX 60 A, p 26] SKEDA 9

PERMA RESEARCH AND DEVELOPMENT COMPANY

Tools and molds located at American Optical Company, Southbridge, Mass.

DESCRIPTION	PART NO.
Tooling	
Punch & Die	132
Progressive die	140
Progressive die	133
Progressive die	122
Progressive die	139
Progressive die	141
Progressive die	RS-4
Progressive die	RS-6
Screw machine cam	RS-9
Progressive die	RS-10
Progressive die	RS-1
Progressive die	RS-5
Moulds	
2 cavities of each	GB-1
" " " "	GB-2-A
" " " "	115
" " " "	117
" " " "	108
" " " "	110
" " " "	109
" " " "	125
" " " "	111
" " " "	PS-2-B
" " " "	136
" " " "	138
" " " "	116
" " " "	PS-9

Drill jig for #103 (weight) (2)
drill jigs for #102 (spider) drill
jig & air press anvils for gear box pin assembly
(a) wood work seats for assembly of 118 (ball stud) to 117 (valve)
(2) fixtures for assembly of 111 (cover plate to 108 (housing)
Air press fixture for pressing G401Y-P (pinion) on GD-4B (shaft
(3) wood multi-cavity work seats for assembly of GS-2-A (cover) to G3-1 (bevel gear housing)

00095

[PX 60A, p, 26]

[PX 60 A, p 27]

SKED A p 10

Tooling located at American Optical Company - Continued 2.

Drill jig for 120 (shaft)
Anvil fixtures to set & stake 107
Det. 3 (Pin)
Anvil fixtures to set & stake 107
Det. 2 (Pin)
Air press fixture for pressing 107 Det. 1
(Pin) into 114 (Ass'y.)
10 Cavity wood nest for assembly of 138 plug & 124 (plug)
10 wood nests for assembly of 110 (Housing) to 108 (Housing)
30 wood nests for assembly of 123 (Posts), reverse parts, switch
133 (bracket, gears & 109 (cover) to 110 (housing)
10 wood nests for assembly of solenoid
10 Station wood nest for soldering leads
20 cavity wood work nest for assembly of 135 (Nut) to 134 (Elbow)
Holding fixture & punch for assembling oil
seal to GB-1 (Housing)
Support fixture & punch for pressing 107
Det. 1 (Pin)
Support fixture & punch for pressing 112 (pin)
Support fixture & punch for pressing 116 (button) on armature
Multi-cavity wood nest soldering of switch parts
Fixture for reaming & tapping of 108 (valve hsg.)
Tapping fixture for PS-2-B (Pressure switch body)
Fixture for drilling & reaming #110 (Gov. Hsg.)
Tapping fixture for 111 (cover plate)
Tapping fixture for 117 (valve)
(2) 7/16 thread depth gauges
Flush pin gauge .343 + .000
- .001
Flush pin gauge .372 + .000
- .001
(2) Angle sight gauges 440
470
(1) fixture for assembly of 104 (Link) to 102 (Spider)
Drill jig for .072 hole in 114 Ass'y.
Holding fixture for rework of 108 (valve Hsg.) to allow installation
of reverse switch.
Holding fixture for rework of 109 (Gear train cover) to enlarge
insert hole to .310
.312
Air press fixture for assembling RS-2 (Pin) to 125 (Drive gear)
Air press fixture for assembling 136 (Button) to 101 (Cam)
Drill jig for .072 hole in 137 (Shaft)
Flush pin gauge for depth of reverse parts hole in 110 (Housing)
(10) .310 ext. .250 int. diam. tubes for centralizing 125 shaft in
109 (Gear train cover)
Set vise jaws & Bushing plate for drilling 120 (shaft)
Set vise jaws & bushing plate for drilling 114 (Assembly)

livered by Seller pursuant to this Agreement, as Buyer or Seller may reasonably request.

E-475 [PX 60A, p 14]

00083

SKEO A p 11

[PX 60.A, p 28]

Tooling located at American Optical Company - Continued 3.

(2) Wood support fixtures for soldering leads including reverse lead
Gauge pin for 102 (Spider)
Location gauge for hole spacing on 110 (housing)
Fixture for reaming & Tapping of 108 (Valve hsg.)
Location gauge & reaming fixture for GB-1 (Bevel gear hsg.)
(10) spring posts for PR17 fixtures
Drill jig for wire lead hole in 110 (housing)
(2) Governor assembly fixtures

Sub - total

Modification of molds & tools for reverse switch

Grand Total

TERMS:

25.0% of total cost of tooling for removal charge.

PX 60A p 28]

00(illegible)

(with copy to Messrs. Winthrop, Stimson, Putnam & Roberts, 30 Rockefeller Plaza, New York 20, New York).

[PX 60A, p 15]

E-476

[PX 60A, P15]

[PX 60A, p 15] 00CR1

[PX 60 A, p 29]

SKED. A

PERMA RESEARCH AND DEVELOPMENT COMPANY

Tools Located at U.S. Dielectric Company, Worcester, Mass.

Tooling to make:

Piston

Piston plug

Hat contact

00026

[PX 60A, p 29]

[PX 60A, p 30]

EXHIBIT 1

THE SINGER COMPANY

Undertaking by THE SINGER COMPANY, a New Jersey corporation (hereinafter called "Buyer"), in favor of PERMA RESEARCH AND DEVELOPMENT COMPANY, a Delaware corporation (hereinafter called "Seller").

WITNESSETH:

WHEREAS, pursuant to an agreement dated December , 1964, between Buyer and Seller (hereinafter called the "Agreement") Seller has concurrently herewith sold, assigned, transferred, conveyed and delivered to Buyer certain assets and patents and patent applications; and

WHEREAS, in partial consideration therefor the Agreement requires that Buyer undertake to assume and agree to perform, pay or discharge certain liabilities and contractual obligations of Seller;

NOW, THEREFORE, in consideration of the premises and other good and valuable consideration, receipt of which is hereby acknowledged, Buyer hereby undertakes and agrees to perform, pay or discharge the liabilities and contractual obligations of Seller listed on Schedule A hereto.

Other than as specifically stated above, Buyer by this Undertaking assumes no liability or obligation of Seller.

This Undertaking shall inure to the benefit of and be binding upon Buyer and Seller and their respective successors and assigns.

THE SINGER COMPANY

By_____

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Schedul A, Page 1

[PX 60 A, p 31]

SCHEDULE OF LIABILITIES AS OF DECEMBER 1, 1964

PERMA RESEARCH AND DEVELOPMENT COMPANY

Date of Invoice	Name and Address of Creditor	Description of Item or Service	Due Date	Amount Due	Terms
9- 1-64	✓Ace Warehouse	Storage	9-10-64	$ 27.95	Net Cash
10- 2-64	389 Charles St.	"	10-10-64	27.95	" "
11- 2-64	Providence, R.I.	"	11- 2-64	27.95	" "
10- 2-64	✓American Airlines	Travel	10-10-64	394.29	" "
10-10-64	633 Third Ave.	"	10-20-64	118.99	" "
	New York, N.Y.				
10-28-64	✓American Express	Lodging and Meals	10- 2-64	71.95	" "
10-22-64	P.O. Box 1934	" " "	11- 2-64	111.69	" "
	Church St. Station				
	New York 8, N.Y.				
6-18-64	✓American Optical	Plate Screws for Anti-Skid	7-18-64	783.28	30 Days N
6-18-64	Southbridge, Mass.	Anti-Skid Units	7-18-64	66.89	" "
6-19-64		Anti-Skid Units	7-19-64	65.31	" "
7- 1-64		16 Gear Boxes	8- 1-64	30.40	" "
9-25-64		Drive Gear Shafts	10-25-64	512.25	" "
9-25-64		Change in Gear Box	10-25-64	2,950.00	" "
4- 1-64	✓Attitude Research	Market Survey Study	5- 1-64	1,700.00	Net Cash
	10 Kettering Rd.				
	Norwood, Mass.				
9- 3-64	✓Automobile Club of R.I.	Equipment for Automobiles	10- 3-64	46.50	" "
	1035 Reservoir Ave.				
	Cranston, R.I.				
7-30-64	✓Avis Rent-A-Car System	Travel	8- 4-64	69.89	" "
	321 S. Cheyenne				
	Tulsa, Okla.				
8-26-64	✓Avis Rent-A-Car System	Travel	8-28-64	39.53	" "
	P.O. Box 201				
	Garden City, L.I., N.Y.				
May	✓Baldwin's Office Supply	Office Supplies	6-10-64	19.72	2% 10th -
	17 N. Washington St.				.30 Net
June	North Attleboro, Mass.		7-10-64	32.42	" "
July			8-10-64	24.12	" "
Aug.			9-10-64	24.24	" "
Sept.			10-10-64	41.55	" "
Oct.			11-10-64	38.84	" "
8-31-64	✓Bright Spot		9-15-64	16.95	2% 15th -
	D.W. Pontious				30 Net
	P.O. Box 3533				
	Columbus 14, Ohio				

300.00

[PX 60A, p 18] 00187

[PX 60A, p 19] 00188

		Amount	
Due Date		Due	Terms
8-10-64	$	21.78	2%-10-Net
9-10-64		4.48	" " " "
10-10-64		13.28	" " " "
11-10-64		1.28	" " " "
5-30-64		80.26	Net 30 Days
6-30-64		48.10	" " "
7-30-64		55.92	" " "
9-30-64		14.40	" " "
10-30-64		10.50	" " "
8-10-64		48.72	2%-10-Net
9-10-64		16.48	" " " "
11-10-64		12.00	" " " "
6-13-64		432.00	Net Cash
9-10-64		197.07	2%-10-Net
10-29-64		18.09	Net Cash
10-25-64		17.65	1%-25-Net
3-25-64		52.67	Net Cash
7-10-64		12.80	Net Cash-10
8-10-64		2.40	" " "
9-10-64		5.21	" " "
10-10-64		2.40	" " "
8-10-64		80.00	" " "
9-10-64		26.50	2%-10-Net
9-10-64		4.98	" " " "
11- 5-64		17.75	Net Cash
11-10-64		3.20	2%-10-Net

[PX 60A, p 32]

00191

[PX 60 A, p 33]

Schedule A Page 3.

-3-

Date of Invoice	Name and Address of Creditor	Description of Item or Service	Due Date	Amount Due	Terms
7-22-64	Danielson Mfg. Co.	Adapters	8-22-64	$ 36.00	Net 30 Days
7-24-64	Danielson, Conn.	"	8-24-64	78.89	" " "
-30-64		"	8-30-64	81.26	" " "
10- 8-64		Cost to Convert Cavities	11- 8-64	450.00	" " "
9- 9-64	E A Dario Company	Auto Expense	10- 9-64	15.23	" " "
10- 5-64	550 Pawtucket Ave. Pawtucket, R.I.	" "	11- 5-64	7.45	" " "
4- 7-64	The Dayton Inn 3rd & Ludlow Dayton 1, Ohio	Lodging	4-20-64	17.46	Net Cash
10-21-64	Dienis, Leo	Traveling	10-21-64	26.63	Net Cash
10-28-64	Perma Res. & Dev. Co.	"	10-28-64	139.11	" "
8-26-64	Fairchild Industrial Parts	Repairs - Projector	9-25-64	7.50	" "
3-30-64	300 Robbins La. Syosset, L.I., N.Y.	Front Projection Kit	4-15-64	25.29	" "
8-7-64	Film Service Lab.	Film	8-22-64	393.56	1%-15-Net
8-7-64	58-62 Berkeley St. Boston 16, Mass.	"	8-22-64	271.67	" " " "
4- 8-64	C J Fox Company P.O. Box 6186 Providence 4, R.I.	2 Color Electros for Adapter Cartons	4-18-64	50.00	Net 10 Days
6- 4-64	The Foxboro Company Foxboro, Mass.	Gauge	7- 4-64	26.38	Net 30 Days
10-14-64	Franklin Hardware Co. 41 Richards Ave. North Attleboro, Mass.	Light Bulbs	11-10-64	5.62	2%-10-Net
2-12-64	General Rental Co. 131 Arlington St. Boston, Mass.	Travel	3- 3-64	28.30	Net Cash
6-24-64	Gothic House	250 Posters	7- 9-64	336.00	Net 15 Days
7-30-64	111 Cherry St.	Repair Charges	8-15-64	49.50	" " "
10- 8-64	Ashland, Mass.	Dupont Reprints	10-24-64	305.00	" " "
May	Robert B. Goldman, Inc.	Advertising & Sales Promotion	6-10-64	826.50	Net 10 Days
June	107 Argell Street	" " "	7-10-64	1,332.29	" " "
July	Providence, R.I.	" " "	8-10-64	368.02	" " "
Aug.		" " "	9-10-64	478.79	" " "
9-22-64	Gulf Oil Corporation	Gasoline	9-24-64	40.91	Net Cash
10-22-64	P.O. Box 7515 Philadelphia, Penn.		10-25-64	107.44	" "

[PX 60A, p 33]

00192

[PX 60 A, p 34]

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Date of Invoice	Name and Address of Creditor	Description of Item or Service	Due Date	Amount Due	Terms
Oct.	Mandees Auto Supply 411 No. Washington St. North Attleboro, Mass.	Miscellaneous Parts	11-10-64	$ 8.04	2%-10-Net
2-26-64	Maskem Bros. Trucking	Transportation from WSM	3-30-64	192.00	Net Cash
4- 2-64	10 Cherry St.	" " "	5-30-64	136.25	" "
	Worcester, Mass.				
8-10-64	Oscar A. Millman & Sons	Zinc Plating	8-30-64	5.60	" "
8-31-64	72-82 Elm Street	Rent	9-30-64	200.00	" "
9-30-64	North Attleboro, Mass.	Rent	10-30-64	200.00	" "
2- 8-64	Milton Inn 3460 Wilshire Blvd. Los Angeles, Cal.	Lodging & Meals	3- 8-64	267.71	Net Cash
3- 9-64	Milray Metal Products	Plating, Reworking Shafts	3-19-64	48.00	1%-10-Net
3- 9-64	104 County Street	& Couplings	3-19-64	87.00	" " "
	Attleboro, Mass.				
10-20-64	Humble Oil & Refining P.O. Box 2140 Church St. Station New York, New York	Gasoline	10-26-64	48.39	Net Cash
1-15-64	Industrial Press 93 Worth St. New York 13, N.Y.	Technical Books	2-15-64	65.20	Net Cash
10-10-64	International Bus. Mach. P.O. Box 1478 Providence, R.I.	Maintenance - IBM	11-15-64	38.00	Net Cash
7-16-64	L.S. Jack - Insurance	Auto Insurance	8-16-64	106.00	" "
8-24-64	185 Village St.	" "	9-24-64	106.00	" "
	Medway, Mass.				
10-30-64	Karp, Sam Perma Res. & Dev. Co.	Travel & Food	10-30-64	17.80	" "
July	Keystone Office Supply	Printing, Reprints		81.40	" "
Aug.	46 Richmond St.	& Stationery		41.50	" "
Sept.	Providence 3, R.I.			49.20	" "
Oct.				2.25	" "
8-21-64	Frank Lizotte's Glass Co. 8 Perry St. Central Falls, R.I.	Repair Sash	9-21-64	4.50	Net 30 Day
June	167 Angell Street				
2-23-64	Lyon Van & Storage Co. 3800 So. Crenshaw Los Angeles, Cal.	Handling Material & Booth for Show	3-23-64	49.55	Net Cash

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Date of Invoice	Name and Address of Creditor	Description of Item or Service	Due Date	Amount Due	Terms
April May June July August	✓Lloyd's Office Supply 52 Union St. Attleboro, Mass.	Office Supply	5-10-64 6-10-64 7-10-64 8-10-64 9-10-64	$ 39.37 29.09 61.19 61.37 55.18	2%-10-Net " " " " " " " " " " " "
1- 2-64 1- 2-64 2-19-64 9- 3-64	✓Magniacomo Inc. Agency 1957 Smith St. Centerdale, R.I.	Insurance - Stock " " 5th Yr. Installment - Bldg. " Building	2- 2-64 2- 2-64 3-19-64 10- 3-64	428.00 594.49 427.20 632.90	30 Days Net " " " " " " " " "
10-27-64	✓Mandeville Chevrolet, Inc. 93 So. Washington St. North Attleboro, Mass.	Repairs on Chevrolet	11-10-64	23.84	2%-10-Net
7-22-64	✓Milton Machine Corp. 40 Oral Road Quincy, Mass.	Prototype Adapters for Cadillac	8-10-64	72.00	1/2% - 10 Net 30
6- 8-64	✓Monte's 707 Fisher Bldg. Detroit 2, Mich.	Lodging & Meals	7- 8-64	67.99	Net Cash
10-23-64	✓J.F. Moran Co. 17 Exchange St. Providence, R.I.	Export Fee	11-23-64	7.50	" "
3- 1-64 9- 1-64	✓Motor & Equipment - Mfg. Assn. 250 W. 57th St. @ Broadway New York 19, N.Y.	Dues & Membership Mem. "	4- 1-64 10- 1-64	150.00 150.00	" " " "
					"
9-30-64	✓N.E. Tel. & Tel. Co. 1 Greene St. Providence, R.I.	YJ 4-4662 - Mobile-Sept.	10-14-64	52.47	" "
10-15-64	✓N.E. Trans. Co. 280 Pine St. Pawtucket, R.I.	Freight - Perma Material	10-22-64	52.19	" "
10-26-64	✓Norman-Duffett Display Inc. 44 Pittsburgh St. Boston 10, Mass.	✓Counter Displays	11- 7-64	2,405.78	1%-10-Net

Schedule A, Page 6

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Date of Invoice	Name and Address of Creditor	Description of Item or Service	Due Date	Amount Due	Terms
10- 6-64	North Attleboro Electric Co.	Electric - Perma 2 9-2 - 10-8-64	11- 5-64	$ 10.25	2.10 Disc
10-29-64	73 No. Washington St. North Attleboro, Mass.	Electric - Perma 1 9-13 - 10-29-64	11-18-64	62.25	15.10 "
8-11-64	N.A. Tire Sales & Service 344 So. Washington St. North Attleboro, Mass.	2 Tires - Pontiac	9-11-64	48.22	Net Cash
5-15-64	Pawtucket Electric & Supply Co. 20 Division St. Pawtucket, R.I.	Repaired Variable Speed Control Box	5-25-64	29.00	Net 10 Day
6-26-64	Perrino, F. Perma Res. & Dev. Co.	Auto Air Conditioner	7-26-64	195.19	Net 30 Day
1-29-64	Pickwick Motor Inn L.I. Expressway @ Exit 48 Plainview, L.I., N.Y.	Lodging & Meals	2-29-64	26.59	Net Cash
8-11-64	Pitney-Bowes Inc.	Postage Meter Repairs & Rental	9-11-64	18.22	Net 30 Day
9- 9-64	69 Walnut St.	" " " "	10- 9-64	7.50	" " "
10-22-64	Stamford, Conn.	" " " "	11-22-64	7.50	" " "
6-18-64	Providence Blue Print Co.	Sepia Paper	7-18-64	34.65	Net
7-21-64	86 Weybosset St.	Print Paper	8-21-64	5.46	"
8-26-64	Providence 3, R.I.	Ammonia & Sepia Paper	9-26-64	30.60	"
10-16-64		K.E. Blueline Paper	11-16-64	5.46	"
9-17-64	Rand Express Freight 1110 Rutherford Ave. Lyndhurst, N.J.	Freight from Singer	9-24-64	58.71	Net Cash
8-25-64	The Regency Hotel Park Ave. @ 61st St. New York 21, N.Y.	Lodging & Meals	9- 2-64	47.32	" "
8-20-64	R.G. Reilly Co. P.O. Box 231 No. Scituate, R.I.	Wheel & Measure Meter	8-30-64	55.00	1%-10-Net
9-25-64	Reynolds & Markman, Inc.	Soap for Demonstrations	10- 5-64	18.00	1%-10-Net
8- 7-64	88 Union Street	" " "	8-17-64	18.00	" " "
8-10-64	Attleboro, Mass.	Counter Display	8-18-64	18.00	" " "
9- 4-64		" " "	9-14-64	9.00	" " "
10- 9-64		Paint & Artist Brushes	10-19-64	2.90	" " "

[PX 60A, p 36]

Schedule A, Page 7

[PX 60 A, p 37]

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Date of Invoice	Name and Address of Creditor	Description of Item or Service	Due Date	Amount Due	Terms
10- 7-64	✓R.I. Spring Parts, Inc. 2310 Pawtucket Ave. East Providence, R.I.	Springs	11- 7-64	$ 10.40	30 Days N.
2- 3-64	✓W.H. Riley & Son, Inc.	Heating System	3- 3-64	242.00	Net Cash
4-28-64	61 No. Washington St.	Oil	5-28-64	21.21	" "
5-18-64	No. Attleboro, Mass.	"	6-18-64	16.77	" "
6- 5-64		Speedi-Dri	7- 8-64	2.75	" "
8-24-64		Oil	9-24-64	5.25	" "
10- 9-64		"	11- 9-64	15.70	" "
10-28-64		"	11-28-64	23.69	" "
3-23-64	✓The Roma	Meals	4-23-64	42.70	" "
6- 5-64	Route 91	"	7- 5-64	8.05	" "
	No. Attleboro, Mass.				
10-31-64	✓Salter & Michaelson 146 Westminster St. Providence, R.I.	Legal Fees Re Patent	11-31-64	438.00	" "
7-10-64	✓Savarin Restaurants	Meals & Lodging	8-10-64	51.36	" "
10- 9-64	131 Varick St.	" "	11- 9-64	12.36	" "
	New York 13, N.Y.				
April	✓Schofield Hardware Co.	Miscellaneous Items	5-10-64	10.22	Net 30 Day
May	54 N. Washington St.	" "	6-10-64	8.50	" " "
June	No. Attleboro, Mass.	" "	7-10-64	1.89	" " "
July		" "	8-10-64	3.60	" " "
Aug.		" "	9-10-64	2.87	" " "
Sept.		" "	10-10-64	3.51	" " "
9-29-64	✓Shell Oil Company P.O. Box 1900 Boston, Mass.	Gasoline & Landing Fees	10-29-64	20.05	Net Cash
9- 9-64	✓Max Silverstein & Son 15 Clarkson St. Providence, R.I.	Magazine Reprints	10- 9-64	20.36	Net Cash
10-19-64	✓The Singer Company	Molded & Machined Adapters	11-19-64	181.40	" "
10-23-64	321 First St. Elizabeth, N.J.	Packing Defective Gears to Return to Vendor	11-23-64	292.43	" "
10-23-64		Packing Defective Material to Return to Vendor	11-23-64	133.50	" "
		Re-work gear boxes 3110 at $1.85 per box	As work performed	5,753.50	
10-13-64	✓Spector Freight Systems	Freight - Sun Electric	10-20-64	7.08	" "
10-20-64	P.O. Box 4437 Chicago, Ill.	" - Car Controls	10-30-64	6.53	" "

[PX 60A, p 37]

[PX 60 A, p 38]

Schedule A. Page 8

-8-

Date of Invoice	Name and Address of Creditor	Description of Item or Service	Due Date	Amount Due	Terms
5-18-64	F.W. Stewart Corp.	Flexible Shaft Assemblies	5-25-64	$ 239.00	Net 10
7- 2-64	4311-13 Ravenswood Ave.	Right Angle Drive Shaft	7-10-64	10.55	" "
7- 2-64	Chicago 13, Ill.	Cables, Nuts & Ferrules	7-10-64	77.04	" "
July	The Stock Market Magazine 209 W. Jackson Blvd. Suite 409 Chicago, Ill.	1/6 Page Ad	August	150.00	Net Cash
2-23-64	Stuart-Sauter Co. 100 Utah Avenue So. San Francisco, Cal.	Rental Furniture for February show	3- 4-64	99.00	Net Cash Receipt of Invoice
1-29-64	Sullivan & Worcester	Legal Services	2-29-64	3,327.26	Net Cash
10-15-64	185 Devonshire St. Boston 10, Mass.	" "	11-15-64	7,857.17	" "
4-14-64	Howard J. Swanson	Accounting Services	5-14-64	540.00	" "
7- 3-64	1429 Warwick Ave.	" "	8- 3-64	375.00	" "
10- 1-64	Warwick, R.I.	" "	11- 1-64	1,645.00	" "
6-4-64	T.S. & W. Inc.	Tubes Slitted	7- 4-64	349.96	Net 30 Days
6-16-64	P.O. Box 153	Drill Jig	7-16-64	96.00	" "
7-13-64	Lincoln, R.I.	Studs	8-13-64	63.00	" "
7-28-64		Studs, Slugs & Threaded Couplings	8-28-64	148.00	" "
8- 4-64		Stud, Bearing & Bushing	9- 4-64	24.00	" "
9- 9-64		Remachining Collars	10- 9-64	64.00	" "
7-20-64	Tasca Ford Sales Inc.	Gears	8-20-64	16.65	Net
8-18-64	777 Taunton Ave.	"	9-18-64	37.60	"
9- 1-64	E. Providence, R.I.	"	10- 1-64	6.95	"
10- 1-64		"	11- 1-64	8.07	"
10-23-64		"	11-23-64	2.95	"
5-19-64	Roland Teinex Co. 134 Tremont St. Everett 49, Mass.	Cams	5-29-64	246.80	1/2 of [illegible] 10 - Net [illegible]
2-18-64	Unit Tool Company Venturi Ave. Warwick, R.I.	RS 1, 4, 5, 6 & 10	3-18-64	457.00	" "

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Date of Invoice	Name and Address of Creditor	Description of Item or Service	Due Date	Amount Due	Terms
10-26-64	United Camera Inc. 297 Elmwood Ave. Providence, R.I.	Verifax Supplies	11-26-64	$ 68.35	Net Cash
1-27-64	U.S. Dielectric Inc. 181 Greenwood St. Worcester, Mass.	Hydraulic Pressure Switches	2- 6-64	313.52	1/2% - 10 Net 30
3- 5-64		PS-8 Contact Rings	3-15-64	20.80	1/2% - 10 Net 30
2-12-64	Universal Pattern & Woodworking Co. 454 George Waterman Rd. Johnston, R.I.	Table Display Stands	2-22-64	360.00	Net 10 Da
6- 9-64	Town of N. Attleboro Collector of Taxes N. Attleboro, Mass.	Real Estate Tax-Shop & Office	7- 1-64	942.50	Net Cash
6- 9-64		" " Billboards	7- 1-64	104.00	" "
9-12-64	Bureau of Corporations Mass. Dept. of Corp. & Tax P.O. Box 355 Boston, Mass.	Corporation Excise Tax	9-15-64	1,749.34	" "
9-30-64	Internal Revenue Serv. 174 Ipswich St. Boston, Mass.	Quarterly Return - Fed. W/H & F.I.C.A.	10-31-64	1,754.31	" "
9-30-64	Internal Revenue Serv. 174 Ipswich St. Boston, Mass.	Quarterly Excise Tax Return	10-31-64	2,411.33	" "
8-31-64	Commonwealth of Mass. Dept. of Corp. & Taxation P.O. Box 1152 Boston, Mass.	Monthly Return-Mass. Income Tax	9-15-64	118.62	" "
9-30-64		Monthly Return-Mass. Income Tax	10-15-64	56.11	" "
10-31-64		Monthly Return-Mass. Income Tax	11-15-64	71.21	" "
9-30-64	Mass. Div. of Employment Security 135 Clarendon St. Boston, Mass.	Employer's Quarterly Contribution Report	10-31-64	242.47	" "
10-31-64	Mfg. Nat'l Bank of EC No. Attleboro, Mass.	Federal Depository Receipt Fed. W/H & F.I.C.A. - Oct.	11-15-64	779.16	" "
11-5-64	Mfg. Nat'l Bank of EC No. Attleboro, Mass.	Fed. W/H & F.I.C.A. - 11-5-64	12-15-64	97.48	" "

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[PX 60 A, p 40]

Date of Invoice	Name and Address of Creditor	Description of Item or Ser.	Due Date	Amount Due	Terms
11/20/64	American Airlines, 633 Third Avenue New York, N. Y. 10017	Travel	12/1/64	$ 389.99	Net
11/23/64	American Express P. O. Box 1934 New York, N. Y. 10008	Lodging & meals	12/3/64	41.51	"
11/19/64	Beauchaine's Inc. 149 Chestnut Street North Attleboro, Mass.	Shop supplies	12/10/64	8.41	2% 1 net
12/1/64	Better Business Bureau 52 Chauncy Street Boston, Mass. 02111	Dues & subscriptions	12/ /64	50.00	Net
11/24/64	Cities Serv. Oil Co. P. O. Box 8494 Philadelphia, Pa. 19101	Gasoline	12/1/64	15.17	"
10/31/64	Corp Brothers, Inc. 1 Brook Street Providence, R. I.	oxygen	11/10/64	2.40	"
11/3/64	Francis H. Curtin Insurance Agency, Inc. 689 Concord Avenue Cambridge 38, Mass.	Workmen's Comp.	11/10/64	573.00	"
11/12/64	George L. Dienes	telephone	11/12/64	36.26	"
11/12/64	Perma Res. & Dev. Co.	"	11/12/64	15.51	"
11/4/64		travel	11/4/64	68.80	"
11/17/64		travel	11/17/64	115.33	"
11/20/64	G. D. C. Leasing Corp. 100 State Street Boston 9, Mass.	rent-equipment lease	12/1/64	8.70	"
10/31/64	Gasoline News 214-216 Oak Street Columbus 15, Ohio	Advertising	11/10/64	15.00	"
11/4/64	Gothic House 111 Cherry Street Ashland, Mass.	brochures	11/15/64	377.00	"
11/19/65	Gulf Oil Corporation P. O. Box 7515 Philadelphia, Pa. 19101	gasoline	11/23/64	85.74	"
11/4/64	Handees Auto Supply	shop supplies	12/10/64	.55	2% 1
11/12/64	411 No. Washington St.	" "	12/10/64	12.42	net 1
11/13/64		" "	12/10/64	18.07	"
11/17/64		" "	12/10/64	7.33	"
11/18/64		" "	12/10/64	9.45	"
11/13/64	The Hertz Corporation P. P. Box 2856 Grand Central Station New York 17, N. Y.	Travel	11/25/64	36.94	Net 0
10/31/64	Oscar A. Hillman & Sons, 72-82 Elm Street North Attleboro, Mass.	Rent	11/10/64	200.00	" "

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10/27/64	Holmes Systems Clearings	Freight	11/3/64	5.20	" "
11/4/64	P. O. Box 329	"	11/11/64	48.60	" "
11/18/64	Bellow Falls, Vermont	"	11/25/64	48.60	" "

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Date of Invoice	Name & Address of Creditor	Description of Item or Ser.	Due Date	Amount Due	
11/10/64	Humble Oil & Refining P. O. Box 2140 Church Street Station New York, N. Y. 10008	gasoline	11/23/64	95.44	N.
11/4/64	Donald Karp Perma Res. & Dev. Co.	travel	11/4/64	30.23	
11/25/64	Sam Karp Perma Res. & Dev. Co.	travel	11/25/64	35.50	
11/4/64	Key Stone Office Supply	Printing & reprints	11/10/64	6.40	Ne
11/9/64	46 Richmond Street	" " "	11/10/64	122.00	Ne
11/30/64	Providence 3, R. I.	" " "	12/10/64	21.30	"
11/5/64	Lloyd's Office Supply 52 Union Street Attleboro, Mass.	office supplies	12/10/64	17.17	"
11/30/64	Mercury Mail Adver. Inc. Dexter Road East Providence, R. I.	addressograph work	12/10/64	11.50	Ne
10/31/64	N. E. Tel & Tel. Co. 1 Greene Street Providence, R. I.	YJ4-4662 - Mobile Oct.	11/10/64	66.66	"
10/28/64	N. E. Tel & Tel. Co. 21 North Main Street Attleboro, Mass. 02703	695-3216 - October	11/10/64	15.07	"
10/28/64	N. E. Tel. & Tel. Co. 21 North Main Street Attleboro, Mass. 02703	699-4608 - October	11/10/64	281.95	"
10/8/64	N. A. E. D. 78 No. Washington St. North Attleboro, Mass.	electricity 10/8/64-11/10	12/1/64	8.95	"
10/8/64	Pierce Chevrolet, Inc.	shop expense	11/10/64	4.06	"
11/4/64	490 Main Street	" "	12/10/64	1.17	"
11/16/64	Pawtucket, R. I.	" "	12/10/64	5.19	"
11/15/64	Pilgrim Interior Cleaners	floors cleaned	11/25/64	32.00	Ne
11/30/64	9 Cameron Street Pawtucket, R. I.	" "	12/10/64	16.00	Ne
10/31/64	Port of New York Authority Treasury Department 111 Eighth Avenue New York, N. Y. 10011	aircraft fees	11/10/64	7.00	N.
11/4/64	Providence Blue Print	office supplies	11/25/64	10.92	N
11/24/64	86 Weybosset Street Providence 3, R. I,	"	12/10/64	2.50	
11/7/64	W. H. Riley & Son, Inc.	fuel oil	12/7/64	17.96	
11/21/64	61 North Washington St. North Attleboro, Mass.	" "	12/21/64	25.61	
11/18/64	The Statler Hilton Washington, D. C.	lodging	11/23/64	88.92	
11/4/64	F. W. Stewart Corp. 4311-13 Ravenswood Ave. Chicago, Illinois 60613	Flexible shafts	12/4/64	42.80	

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Schedule A, Page 12

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Date of Invoice	Name and Address of Creditor	Description of Item or Ser.	Due Date	Amount Due	Terms
11/9/64	The Singer Company	Anti-skid units	12/9/64	700.00	Net Ca.
11/11/64	321 First Street	SK's, VK's, & adapters	12/12/64	8,807.70	"
12/64	Elizabeth, New Jersey	Miscellaneous parts	12/12/64	226.80	"
11/16/64		SK's, VK's, & adapters	12/16/64	69.00	"
11/16/64		Molded adapters	12/16/64	20.00	"
11/17/64		machined adapters	12/17/64	7.80	"
11/27/64		adapters	12/27/64	15.60	"
11/24/64	Stone Ends Brook Street Attleboro, Mass.	Meals	12/10/64	15.80	"
10/21/64	Tasca Ford Sales, Inc. 777 Taunton Avenue East Providence, R. I.	Shop expense	11/10/64	12.83	"
11/20/64	Texaco Inc. 130 East 43rd St. New York, N. Y. 10017	gasoline	11/30/64	25.61	"
12/1/64	U. S. Corp. Company 50 Broad Street New York, N. Yl. 10004	statutory representation	12/1/64	35.00	"
11/6/64	United Camera Inc.	office supplies	12/10/64	16.50	"
11/19/64	297 Elmwood Avenue	Verifax supplies	12/10/64	88.85	"
11/20/64	Providence, R. I. 02907	" "	12/10/64	14.85	"
11/20/64		" "	12/10/64	(11.85)	"
11/1/64	Western Union Attleboro, Mass.	telegrams	12/1/64	16.72	"
11/13/64	Yale Express System P. O. Box 6000 New York 1, N. Y.	freight	11/13/64	5.10	"
	J. A. Krawczyk	retroactive wages through 11/4/64		1,644.48	"
	R. D. Mainelli	" " "	"	445.50	"
	S. Karp	" " "	"	1,950.00	"
	F. Di Benedetto	" " "	"	363.43	"
	F. Perrino	" " "	"	3,028.80	"
	A. Petit	" " "	"	496.00	"
	D. Karp	" " "	"	125.00	"
	G. Dienes	" " "	"	1,915.40	"
	Payroll	through 11/28/64 - gross		6,187.11	"
10/31/64	Internal Revenue Ser.	Excise tax - Oct.	11/15/64	47.91	"
11/30/64	174 Ipswich Street Boston, Mass.	" " - Nov.	12/15/64	1,059.28	"
	Payroll taxes	November	12/30/64	595.57	"
	Blue Cross	November	11/20/64	224.90	"
		Sub-total, pages 1-12		$85,312.66	

LIABILITIES

FERMA RESEARCH AND DEVELOPMENT COMPANY

SCHEDULE OF NOTES PAYABLE AS OF DECEMBER 1, 1964

Name and Address of Creditor	Description of Item or Service	Monthly Due Dates	Original Amount	Payments	Balance Due	Terms
Advanced Control Systems 315 Harvard Street Brookline, Mass.	Former Dealer	1	$ 10,868.00	418.00	5,016.00	Monthly
G.D.C. Leasing Corporation	Leasing of Projectors	1	1,928.52	53.57	53.57	"
G.D.C. Leasing Corporation 100 State Street Boston 9, Mass.	Leasing of Postage Meter	29	1,548.00	25.80	696.60	"
Small Business Administration 470 Atlantic Avenue Boston, Mass.	Small business loan	20	150,000.00	2,763.00	82,320.09	"
Notes Payable - Stockholders						
Vincente Fenta			10,000.00		10,000.00	
J.A. Krzeczyk			19,639.00		15,264.00	
Frank Di Benedetto			2,000.00		2,000.00	
Advance Billings to Stockholders			5,000.00		2,700.00	Payment in 27 units
Suttell Motors					3,439.21	
Bald Hill Sunoco					425.00	
Anthony's Service Station	Former Dealer				2,470.00	
				Sub-total, notes payable	124,394.47	
				Sub-total, PAGES 1-12	85,312.66	
				Total liabilities assumed	$209,697.13	

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PERMA RESEARCH AND DEVELOPMENT CO.
PURCHASE ORDER COMMITMENTS
(CONTRACTUAL OBLIGATIONS)

Date of P.O.	Supplier's Name and Address	Description of Item or Service	Amount of Commitment	P.O. Number
3/13/64	Cinecom 960 S. Birch Street Denver 22, Colorado	Films & [illegible]	$204.00	001592
7/27/64	Daniel[illegible]g. Co. Danie[illegible] Conn.	Cut down adapter shaft	344.00	001639
8/5/64	Daniel[illegible] Mfg. Co. Danielson, Conn.	" " " "	84.00	001642
8/29/64	Cinecrom Laboratories 4075 Transport St. Palo Alto, California	25 copies of 8 MM color sound film	937.50	001661
11/2/64	The Singer Company 321 First Street Elizabeth, New Jersey	adaptors	24.00	001671
11/9/64	Industrial Suppliers 755 Folsom Street San Francisco, Cal.	Whip antennae	10.00	001675

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[PX 60 A, p 45]

PERMA RESEARCH AND DEVELOPMENT COMPANY

Distributor Contracts

1. Wholesale distributor agreement dated April 15, 1964 by and between Perma Research and Development Company and Thomas H. Coulter of Des Moines, Iowa.

2. Agreement dated August 4, 1964 by and between Perma Research and Development Company and Monitor Enterprises, Inc.

3. Agreement dated July 24, 1963 by and between Perma Research and Development Company and Edward B. Wright, Jr (signed by "Car Controls, Inc.").

4. Wholesale distributor agreement dated May 1, 1964 by and between Perma Research and Development Company and Jandro Equipment Co., Minneapolis, Minnesota.

3600 So. Grand Booth for Show 3-23-64 49.55 Net Cash
Los Angeles, Cal.

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[Px 60 A, p 46]

PERMA RESEARCH AND DEVELOPMENT COMPANY

PROMISSORY NOTE

$ 209,697.13 December 21, 1964

FOR VALUE RECEIVED, PERMA RESEARCH AND DEVELOPMENT COMPANY, a corporation organized and existing under the laws of the State of Delaware, does hereby promise to pay to the order of the

THE SINGER COMPANY

a corporation organized and existing under the laws of the State of New Jersey, on December 20, 1969 the sum of TWO HUNDRED NINE THOUSAND SIX HUNDRED NINETY SEVEN and 13/100 DOLLARS ($209,697.13), without interest. This note or any portion thereof may at any time and from time to time be prepaid without penalty.

PERMA RESEARCH AND DEVELOPMENT COMPANY

By _____
President

[PX 60A, p 46]

[PX 60 A, p 47]

AGREEMENT, dated the day of December, 196[illegible], by and between THE SINGER COMPANY ("Singer"), a New Jersey corporation, and PERMA RESEARCH & DEVELOPMENT COMPANY ("Perma"), a Delaware corporation.

W I T N E S S E T H :

WHEREAS, Perma has simultaneously herewith conveyed certain patents and patent applications relating to the United States and Canadian rights in the "Perma Anti-Skid Control" (the "Product") and certain tools used in the manufacture thereof; and

WHEREAS, Perma has certain testing facilities for the Product and know-how with respect to the manufacture, marketing and use of the Product,

NOW, THEREFORE, in consideration of the premises, the parties agree as follows:

1. Perma shall, at the request of Singer, render technical assistance to Singer which shall include assisting, consulting and cooperating with Singer:

(a) in the adaptation of the Product for use on all makes of automobiles and trucks and all types of motor vehicles of every kind and description;

(b) in the preparation and designing of drawings, blue prints, design sheets, bills of material, speci-

fications and the like from which the Product and its various components can be manufactured, and the preparation of similar documents and materials from which the manufacturing equipment, tools, dies and the like can be made for use in manufacturing the Product;

(c) in the continuing design and engineering and improvement of the Product and of the equipment for manufacturing the same and in the setting up and operation of such equipment, including advice relating to the nature and sequence of manufacturing operations;

(d) in the marketing of the Product; and

(e) in the design and manufacture of prototypes of various new models of the Product for use on various models of automobiles, trucks and other motor vehicles.

2. Perma shall send qualified personnel to the manufacturing facilities of Singer or such other place as Singer may designate from time to time at Singer's request in connection with Perma's obligations under Section 1. The reasonable travel and living expenses of any such personnel shall be paid by Singer. Perma shall during the time of this Agreement make the services of Frank A. Perrino available in connection with its obligation hereunder.

3. Perma shall train selected employees of Singer at the plant and the facilities of Perma with respect to all phases of the manufacture, installation,

marketing and use of the Product.

4. Perma shall install the Product on test cars provided by Singer or Perma and shall perform tests thereon at the testing facilities of Perma as reasonably requested by Singer and shall report to Singer concerning the results of such tests.

5. Singer shall pay Perma $9,800 per month in monthly installments in advance for the services to be performed by Perma hereunder.

6. This agreement shall commence upon the date hereof and shall continue for a term of six months.

IN WITNESS WHEREOF, the parties hereto have executed this agreement as of the date first above written.

THE SINGER COMPANY

Attest:

By_____

_____

PERMA RESEARCH AND DEVELOPMENT COMPANY

Attest:

By_____

_____

PLAINTIFF'S EXHIBIT 62

THE SINGER COMPANY

THIRTY ROCKEFELLER PLAZA • NEW YORK 20, NEW YORK

MANUFACTURING DIVISION

PP:AM
January 7, 1965

STATE EXH 20-A
FOR IDEN.
IN EVID. DATE 3/11/71
LAWRENCE GREENBERG

Mr. Broad

Mr. S. J. Murphy
The Singer Company
321 First Street
Elizabeth, New Jersey

Dear Mr. Murphy:

PERMA ANTI-SKID PROGRAM

Mr. Hough has asked me to document certain points of emphasis which we have discussed from time to time during the negotiations with Perma, which are enumerated as follows:

1. One individual should be responsible for the entire program and the coordination of all aspects thereof and be answerable directly to the managing director.

2. The Perma program is of sufficient magnitude and complexity that the responsible designee should have no other duties or responsibilities at least for the first full year of operation.

3. We have in this program an investment and commitments amounting to something in excess of one million dollars and in view of this it is of utmost important that we spend no additional monies and generate from cash flow as quickly as possible with the prime objective to cut down this investment as rapidly as possible.

4. The product should have the full and enthusiastic support of the factory.

5. At least for the first six months and possibly longer, close liaison should be maintained with Monitor for various reasons.

   a. Never allow Monitor to want for product.

   b. Assurance that Monitor is abiding by its agreement as regards promotional expenditures, etc.

   c. Observe and learn problems of selling and installation in the event that another distributer might be desired after one year.

6. Anticipate requirements so live stock is always available.

7. Program proto-typing to provide broad coverage of as many auto types as possible.

8. Keep very accurate records of tests in the event of litigation.

9. Avoid using Singer name on product until satisfied product warrants use of name and same would be advantageous.

10. Work the Perma service contract to the fullest extent possible to obtain the full value of this expenditure. Under this agreement we are paying out $9000. plus per month and we should make certain that we are getting $9000. plus per month from Perma. This will in effect mean that we should keep them so busy that they never get a chance to come up for air and drift off into other projects which are not of our concern.

11. Be familiar with Sherman Anti-Trust areas as pertaining to territories and pricing.

12. Check and approve Monitor's promotional material if our legal people so recommend.

13. Prepare a set of engineering specifications around the product with emphasis on its limitations under a variety of conditions.

In conclusion, we have by the acquisition of the Perma Anti-Skid Device, gotten ourselves into a program that could very well be a big and profitable piece of business for Elizabeth. By the same token, if we blow it we stand to lose a substantial sum of money equal to more than half of Elizabeth's profit potential, not to mention the fact that certain divisions and officials are watching this program with a jaundiced eye, and therefore, it should have as much attention as a sewing machine program.

P. Phelps

cc: Mr. L. E. Hough, E.O.
Mr. R. Kloby, Elizabeth

NO MATERIAL ON PAGE E-514

PLAINTIFF'S EXHIBIT 63

EXH. NO. 33A
BORAK, REPORTERS
11/18/70

February 17, 1965

Mr. P. Phelps, Manager
Marketing & Diversification
The Singer Company
Manufacturing Division
30 Rockefeller Plaza
New York 20, New York

Perma Anti-Skid Program

Dear Mr. Phelps:

In reply to your letter of January 7, 1965, we present the following information regarding the items mentioned:

1. Mr. Robert A. Kloby has been named Manufacturing Manager for Perma. In this capacity he answers directly to Mr. John Fecko, Manager of the General Fabrication Division. Mr. Kloby is responsible for the entire product line, which includes marketing, production and engineering. Mr. Kloby will continue to report to the Division Manager of the General Fabrication Division until such time the product line growth indicates that it should be a separate division within the factory.

2. Mr. Kloby will have no other duties other than the full responsibility of the Perma Program.

3. Every additional expenditure for the Perma product line is being scrutinized thoroughly by this office. No additional monies are being spent unless absolutely necessary, in order to control our total investment.

4. The Perma product has been publicized and enthusiastically received by all personnal in this factory. All personnal associated with this product line are making every effort to see that it continues to grow.

In order to give you a more concise reporting on items 5 through 12, we have asked Mr. Kloby to prepare an answer based on events to date, a copy of which is attached.

Please rest assured that every effort is being made to see that the Perma unit will be profitable and will grew to a point where it will be a major contributor to our profits here at Elizabeth and to the Manufacturing Division.

Yours very truly,

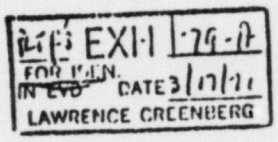
Carl W. Brocker
Assistant General Manager

CWB:hl

Encl.

CC: Mr. L.E. Hough

PLAINTIFF'S EXHIBIT 64



Conformed

AGREEMENT dated the 18th day of January, 1965, by and between THE SINGER COMPANY ("Singer"), a New Jersey corporation with principal offices at 30 Rockefeller Plaza, New York, New York 10020, and MONITOR ENTERPRISES, INC. ("Monitor"), a New Jersey corporation with principal offices at 22 East 42nd Street, New York, New York 10017,

W I T N E S S E T H:

WHEREAS, Singer is the owner of United States and Canadian rights in and to a certain invention or device (the "Perma Anti-Skid Control") to control braking skids in certain vehicles (such Perma Anti-Skid Control and any improvement or modification thereof being hereinafter referred to as the "Product"); and

WHEREAS, for convenience of marketing, the Product is divided into three components, to wit: a Static Kit, a Variable Kit, and an Adapter; and

WHEREAS, Monitor is desirous of becoming the sole distributor for the Product in the United States, except as herein provided; and

WHEREAS, Singer desires to be assured of the services of Joseph W. Kelley in connection with such distributorship,

NOW, THEREFORE, in consideration of the premises and for other good and valuable consideration, it is

agreed as follows:

1. (a) Grant. Singer hereby grants to Monitor upon the terms and conditions hereinafter set forth the exclusive distribution and marketing rights in the Product in the United States of America, subject to the respective rights of Singer and the distributors under the following contracts:

1. Wholesale distributor agreement dated April 15, 1964 by and between Perma Research and Development Company and Thomas H. Coulter, Des Moines, Iowa.

2. Agreement dated July 24, 1963 by and between Perma Research and Development Company and Edward B. Wright, Jr. (signed by "Car Controls, Inc.").

3. Wholesale distributor agreement dated May 1, 1964 by and between Perma Research and Development Company and Jandro Equipment Co., Minneapolis, Minnesota.

(b) Termination of Prior Agreement. The Agreement dated August 4, 1964 by and between Perma Research and Development Company and Monitor, the rights and duties under which of Perma Research and Development Company Singer has succeeded to, is terminated simultaneously with the execution of this Agreement without liability of either party thereunder to the other except any liability of Monitor for payment for Products delivered by Singer pursuant thereto.

2. Promotion. Monitor shall continuously sell, market, promote and advertise the Product throughout the United States and shall at all times employ its best efforts and devote its full time and resources in connection

therewith. Monitor shall incur direct out of pocket promotional and advertising expenses on behalf of the Product of a minimum of $250,000 in each contract year during the term of this Agreement. Any such expenses in excess of $250,000 in any contract year shall not be available for credit in any subsequent contract year. "Direct out of pocket promotional and advertising expenses" shall be limited to expenses of Monitor on behalf of the Product for time, space, production by third parties, direct mail, brochures and similar advertising materials, amortization over the useful life thereof of expenses for films concerning the Product and rental of or amortization of the cost of movie projectors in connection therewith. Monitor will devote the services of a minimum of eight full-time employees, including Joseph W. Kelley, Highland Lakes, New Jersey, exclusively to the marketing, advertising and promotion of the Product. Singer through its authorized representatives shall have the right at any time to examine the books and records of Monitor relating to the Product and Monitor's marketing, advertising and promotion thereof. In the event Monitor's initial minimum purchase requirements hereunder in any contract year are reduced, by operation of the last sentence of Section 7 hereof, by over 25% of such requirements, Monitor's minimum direct out of pocket promotional and advertising expenses for such contract year shall be reduced by 25%; and in the event such purchase requirements are so reduced by over 50%, such minimum expenses shall be reduced by 50%.

3. Advertising Material. Monitor shall incorporate in all advertising and promotional material the name "Perma Anti-Skid Control" or such other trade name as Singer may establish from time to time, and Monitor shall identify, offer, sell, advertise and promote the Product only by such names and trademarks as may be authorized in writing by Singer. For purposes of protecting Singer's valuable trademarks and trade names, Monitor shall submit all advertising, promotional and public relations material making reference to "Singer" or any other trade name or trademark of Singer to Singer in advance of use for Singer's approval and shall use only such material as is approved by Singer. Any such material so submitted which Singer does not object to within ten (10) days of such submission shall be deemed approved.

4. Acknowledgment. Monitor agrees that all patents, trademarks or copyrights now or hereafter obtained by Singer or its successors or assigns relating to the Product or the manufacture thereof shall be the exclusive property of Singer. Monitor will not dispute the validity of any such patents, trademarks or copyrights, or Singer's title thereto, and will not aid others in doing so and will not avoid or attempt to avoid its obligations hereunder because of any asserted invalidity or contested ownership of Singer thereto.

5. Infringements. In the event that Monitor shall learn of any infringement of any of Singer's patents on the Product, Monitor shall notify Singer thereof in

writing and provide Singer with any available evidence of infringement. In any infringement suit which Singer may institute, Monitor shall, at the request of Singer, cooperate with Singer in all respects making available to Singer all relevant records, papers, information, specimens and the like and make all reasonable efforts in good faith to secure the testimony of Monitor's employees and other evidence available to it.

6. Original Equipment Manufacturers; Employees. Monitor shall continuously use its best efforts to make sales of the Product to manufacturers of motor vehicles ("Original Equipment Manufacturers"). Singer reserves the right to make sales of the Product direct to Original Equipment Manufacturers at factory invoice prices determined by Singer, but shall pay a commission of 2% of such factory invoice price to Monitor on all such sales to Original Equipment Manufacturers. "Factory Invoice Price" means invoice price less Federal excise tax, sales tax, discounts and shipping costs. Singer further reserves the right to make sales at prices determined by Singer to its employees, its subsidiaries, employees of subsidiaries and a limited number of other persons having close business relations with Singer.

7. Minimum Purchase. Monitor agrees to purchase for resale in the United States a minimum of 50,000 units of the Product available from Singer in the first contract year of this Agreement at a purchase price of $51.00 per unit for the Standard SK Model and Singer's

factory billing price to distributors in effect from time to time on other models of the Product, f.o.b. Singer's manufacturing facility, to be delivered at Singer's manufacturing facility in accordance with Schedule A hereto. In addition, Monitor shall purchase such additional number of Variable Kits and Adapters and other spare parts as necessary properly to take care of the needs of the market. During said first year of this Agreement, the purchase price of the components of the Product, f.o.b. Singer's manufacturing facility, shall be as follows:

	Standard SK Model	Other Models
Static Kit	$44.55	Singer's Factory Billing Price to Distributors In Effect From Time to Time
Variable Kit	$ 5.15	" "
Adapter	$ 1.30	" "
Spare Parts	Singer's Factory Billing Price to Distributors in Effect from Time to Time	

Payment terms for all Products, components thereof and spare parts therefor sold to Monitor shall be thirty days net. If Singer fails for seven consecutive days to deliver Products in accordance with Schedule A attached hereto, or any delivery schedule applicable to any subsequent contract year of this Agreement, the minimum number of units to be purchased by Monitor during such contract year shall be reduced by the number of units which Singer so failed to deliver according to schedule.

8. Spare Parts. In recognition of the imperative

need for quality control and proper installation in connection with the Product, Monitor will market and sell only those spare parts for the Product which have been authorized and approved in writing by Singer. Monitor will include a provision similar to this provision in any sub-distributor and dealer contract relating to the Product which it may execute and similarly require any sub-distributor to do the same.

9. Term and Renewal Option. The term of this Agreement shall be one year from the date hereof unless renewed in accordance herewith. "Contract year" as used herein means a period of one year from the date hereof or one year from any anniversary date hereof. If Monitor is not in breach of this Agreement upon the expiration of one (1) year from the date hereof, Monitor shall have the right to renew this Agreement for an additional contract year. Exercise of such option shall be effected by written notice to Singer delivered at least sixty (60) days prior to the expiration of one (1) year from the date hereof. In the event Monitor exercises such option, it will purchase a minimum of 100,000 units of the Product in the second contract year of this Agreement at Singer's factory billing price to distributors in effect from time to time in accordance with a delivery schedule to be agreed upon by the parties hereto. Singer shall give written notice to Monitor ninety days prior to the end of the second, third and fourth contract years, if any, of the minimum number of units of the Product to be purchased by Monitor in the subsequent contract year and Singer's

initial factory billing price to distributors therefor. Monitor shall have the right, in the second, third and fourth contract years, if any, by written notice to Singer delivered sixty (60) days prior to the end of the contract year, to renew this Agreement for one (1) year, if Monitor is not in breach of this Agreement at such time or at the end of the contract year, and Monitor shall be required to purchase in the contract year to which such renewal is applicable the minimum number of units specified by Singer in such notice at Singer's factory billing price to distributors in effect from time to time in accordance with a delivery schedule to be agreed upon by the parties hereto.

10. Models. By August 1 of each year during the term of this Agreement, Monitor shall give written notice to Singer, listing each make and model automobile for the subsequent model year which it wishes to be prototyped, in order of importance to Monitor. Singer shall, within six (6) weeks of public introduction of each such make and model, notify Monitor of its progress in prototyping such make and model and will generally consult from time to time with Monitor with respect to availability of a Product for various new makes and models. Singer shall provide a list, which it shall keep current, of all vehicles by make and model (including model year) for which a Product is available, and Monitor's minimum purchase requirements hereunder must be made from such list.

[PX 64, p 9]

11. Standards. Monitor shall conform to standards and technical instructions from time to time issued by Singer with respect to installation, service, maintenance, repair and replacement of the Product. Monitor will insert a provision similar to this provision in any sub-distributor and dealer contract relating to the Product which it may execute and similarly require any sub-distributor to do the same.

12. Default. In the event of failure on the part of Monitor to pay any sums due to Singer, and such failure shall continue for a period of thirty (30) days, or in the event of failure on the part of Monitor to perform any other of its obligations hereunder, and such failure shall continue for a period of thirty (30) days after notice and demand by Singer, or in the event that Monitor makes an assignment for the benefit of creditors or files a petition under any bankruptcy or similar law or such a petition is filed against Monitor and not vacated within thirty (30) days, this Agreement shall immediately be subject to termination by Singer at its sole option.

13. Warranty. Singer recognizes that Monitor is relying on Singer's skill and judgment in the design and manufacture of the Product and Singer warrants to Monitor that the Product shall be free from defect in design, materials and workmanship, that Singer's instructions for the installation and application of the Product shall be free from material defect and that the Product

is merchantable and is fit for the ordinary purposes for which the Product is used, and makes no other warranties, express or implied. Singer shall also warrant to ultimate purchasers of the Product for one year after installation that the Product shall be free from defect in design, materials and workmanship, and shall make no other warranty to such purchasers, express or implied. If a claim is made that any such warranty is breached, the Product or component thereof shall be shipped prepaid to Singer's manufacturing facility with adequate evidence of such breach and such Product or component thereof shall be repaired or replaced. Singer shall not be liable for any loss or damages to Monitor or to any other person arising from any delay or failure by Singer to meet the delivery schedule set forth on Schedule A hereto or delay or failure to meet any other delivery schedule hereunder or orders of Monitor for the Product.

14. Indemnity. In addition to Product replacement referred to in Section 13, Singer shall indemnify and hold harmless Monitor from and against any and all claims, losses, damages and liabilities to which Monitor may become subject and reasonable expenses incurred in the investigation and defense thereof insofar as such claims, losses, damages or liabilities arise out of, are based upon or owing to a breach of Singer's warranty in Section 13 hereof or Singer's negligence.

Monitor shall indemnify and hold harmless Singer from and against any and all claims, losses, damages and liabilities to which Singer may become subject

[PX 64, p 11]

and reasonable expenses of investigation and defense thereof insofar as such claims, losses, damages or liabilities arise out of, are based upon or owing to any warranty made by Monitor, its sub-distributors or dealers of greater scope than those made by Singer in Section 13 hereof, negligence of Monitor, its sub-distributors or dealers or any alteration or misapplication of the Product or failure to follow Singer's instructions and specifications by any of the foregoing.

If any action or proceeding shall be commenced against or any claim, demand or assessment be asserted against either party in respect of which such party proposes to demand indemnification, such party shall notify the other party to that effect with reasonable promptness and the other party shall have the right to assume the entire control of the defense, compromise or settlement thereof, including, at its own expense, employment of counsel satisfactory to such party and, in connection therewith, such party shall cooperate fully to make available to the other party all pertinent information under its control. The party claiming indemnification may, if the indemnifying party assumes control of the defense, nonetheless participate in any such action or proceeding at its own expense, and the indemnifying party shall not be liable to the other party for legal and other expenses incurred after giving notice of its election to assume control of the defense.

Monitor and Singer shall each give the other a certificate of insurance certifying as to coverage of

claims for which indemnity is made by such party in the minimum amount of $5,000,000.

15. Right to Repurchase. In the event of termination of this Agreement for any cause whatsoever, Singer shall have the right for thirty (30) days after such termination to purchase all Products, components thereof and parts therefor in the inventory of Monitor at the time of termination at the price paid by Monitor therefor less a handling charge of fifteen percent (15%) of such purchase price.

16. No Agency. Nothing herein contained shall be construed to constitute Monitor an agent of Singer for any purpose.

17. Assignment. This Agreement shall not be assigned by Monitor voluntarily or by operation of law and any attempt by Monitor to assign this Agreement shall immediately give rise to an option of Singer to terminate this Agreement.

18. Notice. Any notice or communication under this Agreement shall be deemed to have been duly given if mailed by first class mail, postage prepaid to the other party to its place of business herein set forth, or such other address as may be furnished to the other party in writing.

19. Entire Agreement. This Agreement constitutes the entire agreement between the parties hereto and may not

be modified or changed except in writing.

20. No Waiver. No failure by either party to take action in respect of any default or breach hereunder shall be deemed to be a waiver of any provision of this Agreement and no waiver of any default or breach or failure to take action shall be deemed to extend to any future default or breach.

IN WITNESS WHEREOF, the parties have executed this Agreement as of the day and year first above written.

THE SINGER COMPANY

By s/ A. T. Mealey
Assistant Vice President

Witness:
s/ Robert R. Kelley

MONITOR ENTERPRISES, INC.

By s/ Francis W. Kelley
President

Witness:
s/ George C. Rollman

SCHEDULE A
TO
AGREEMENT DATED JANUARY 18, 1965
BY AND BETWEEN
THE SINGER COMPANY AND MONITOR ENTERPRISES, INC.

Monitor shall take delivery from Singer and remove from Singer's manufacturing facility and Singer will so deliver to Monitor the following number of units of Product in each of the weeks indicated. As soon as practicable, Monitor shall start delivering to Singer four weeks prior to scheduled delivery written notice of the exact makes and models (which must be available from Singer in accordance with Section 10) of variable kits and adapters required as part of ordered units.

Date (1965)	Number of Units	Date (1965)	Number of Units
January 30	140	May 1	400
February 6	140	8	500
13	140	15	500
20	140	22	500
27	150	29	500
March 6	150	June 5	540
13	250	12	540
20	250	19	540
27	250	26	540
April 3	400	July 3	540
10	400	10	540
17	400	17	540
24	400	24	540

Thereafter, Monitor shall so take delivery and Singer shall so deliver 1,602 units per week for the next succeeding five weeks and 1,603 units per week for twenty weeks next succeeding such five weeks.

DEF. EX.

PLAINTIFF'S EXHIBIT 65A

THE SINGER COMPANY

ELIZABETH PLANT • 601 FIRST STREET, ELIZABETH, NEW JERSEY • 201 EL 2-8500

December 23, 1964

Mr. Frank A. Perrino, President
Perma Research and Development Company
345 E. Washington
North Attleboro, Massachusetts

Dear Mr. Perrino:

In accordance with our contract agreement we solicit the following engineering services.

DESCRIPTION OF SERVICE	DATE REQUIRED
I. Dual Perma-vac Unit:	
a. Provide test specifications for Dual Perma-vac Unit with documented engineering test data used to develop specification. Documented engineering data must include information relating car speed, locking pressure and effect on stopping distance for all road conditions.	12/28/64 or sooner
b. Provide test master for Dual Perma-vac Unit. Unit now in your possession with test data would suffice.	12/28/64 or sooner
c. Provide schematic diagram of dual hydraulic system.	12/28/64 or sooner
II. Single Piston Perma-vac Unit:	
a. Provide documented engineering test data relating car speed, locking pressure and effect on stopping distance for all road conditions for Single Piston Type Perma-vac Unit.	12/28/64 or sooner

379

DESCRIPTION OF SERVICE	DATE REQUIRED
b. Investigate and recommend possible design changes which would increase the yield of single piston type Ferma-vac Units which would meet the original 700 p.s.i. minimum pressure after vacuum. Specification was reduced to 600 p.s.i. due to large percentage of rejects. Unless the data in II-a. indicates favorable conditions at this pressure, we must find a design which will yield consistent and higher results.	2/22/65
III. Sensing Unit:	
a. Perform dimensional analysis of components affecting clearance between Governor Spool face and Delrin boss of Sensing Unit and recommend tolerance changes to insure proper clearance at assembly. Provide assembly drawing showing recommended changes in tolerances of components.	2/1/65
b. Provide documented engineering test data relating pulse response time of sensing unit to car speed, locking pressure and stopping distance for all road conditions.	2/8/65
IV. Disc Brake System:	
a. Provide engineering data relating locking pressure, car speed and stopping distance for all road conditions for Disc brake hydraulic system. Provide schematic diagram of system.	4/19/65

DESCRIPTION OF SERVICE	DATE REQUIRED
b. Provide preliminary design and calculations for prototyping system to accommodate Disc brake system. Design should utilize as many existing parts as possible.	6/21/65

V. General Engineering and Test Information:

a. Maximum torque loads (Static and Shock) that can be applied to all torque transmitting components. Include documented test data and/or calculations to substantiate findings.	2/15/65
b. Provide existing documented environmental and endurance test data on Sensing Unit, Gear Box, Adaptors and Perma-Vac Unit.	1/4/65
c. Provide documented test data on environmental testing of sample F. W. Stewart gear box now in your possession.	2/1/65
d. Provide engineering data relating car speed, locking pressure and effect on stopping distance for conventional brake system for all road conditions.	12/28/64
e. Provide a list of testing facilities available at Perma.	1/4/65

We are enclosing a copy of the "Experimental and Test Data Sheet" used at Singer to document data. We ask that a similar method be used by Perma on all current and future tests. If you would like to use this form we will be glad to supply a quantity of these upon your request. If the above information cannot be supplied by the required date, please let us know in writing when

it will be available. We feel that most of the information should be on file in your plant as it pertains to your original design and should have been recorded or obtained during the development stage.

Very truly yours,

THE SINGER COMPANY

A. Romel

A. Romel, Manager
Manufacturing Engineering
Contract Sales

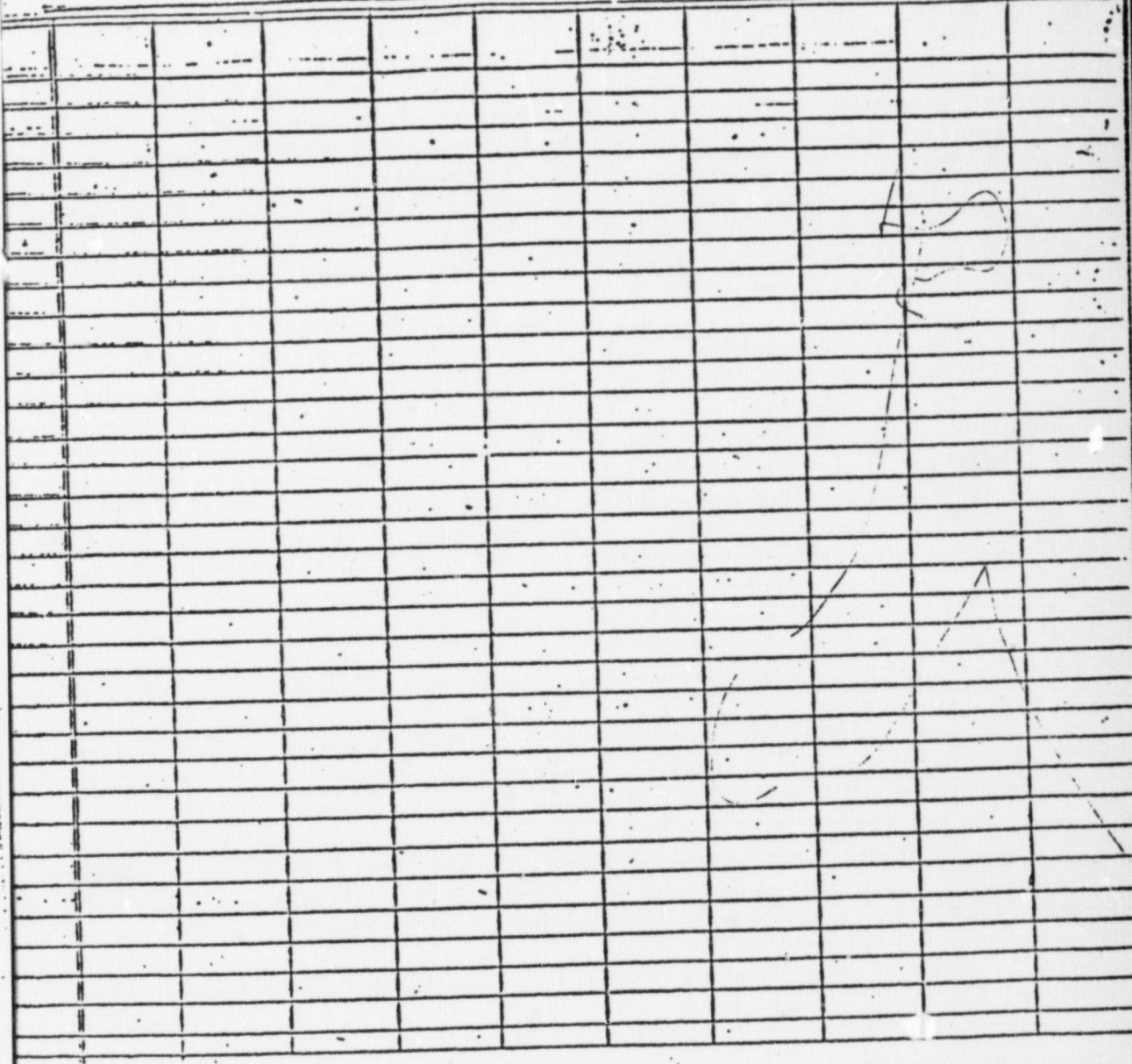
Encl.

AR/ms

cc: Messrs. C. W. Brocker
J. Fecko
D. A. Adams
R. Kloby
H. Sharp

TEST EQUIP. NO. _____

DESCRIPTION _____



REMARKS:

PLAINTIFF'S EXHIBIT 77

MEMORANDUM

SINGER
321 FIRST STREET · ELIZABETH, N. J.

TO: Mr. E. A. Sprague, Manager - Central Engineering Staff
Manufacturing Division

FROM: A. Romel

DATE: May 10, 1965 REFER TO:

SUBJECT: Original Sketches of Transfer Valve

Dear Sir:

Enclosed are the original sketches of the transfer valve made by Mr. Perrino and I on April 7, 1965 along with a description of its function in relation to the Perma-Vac Unit. Please take the necessary steps to check out our patent position. Working drawings and additional information can be supplied upon request.

Very truly yours,

GENERAL FABRICATION DIVISION

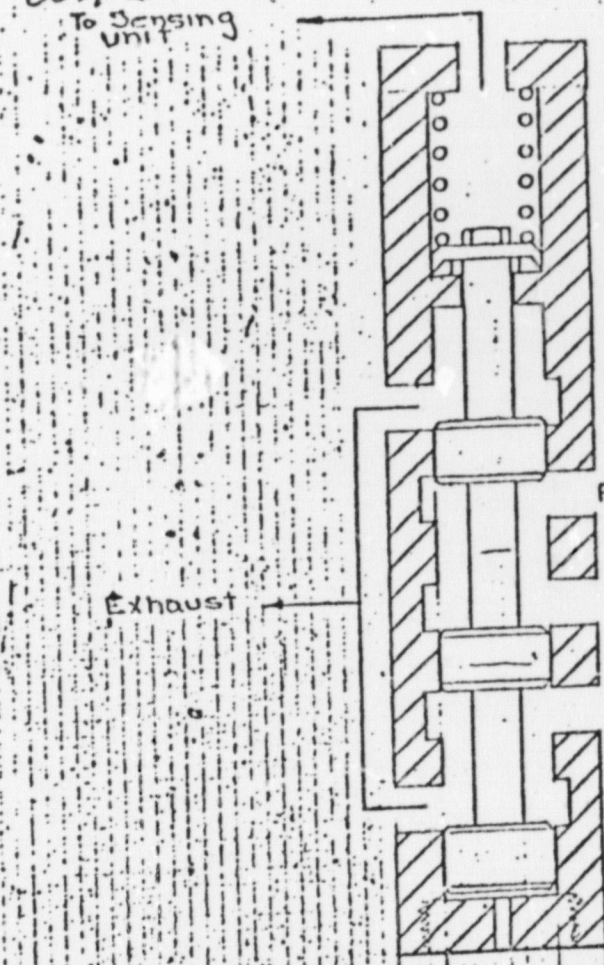
A. Romel

A. Romel, Manager
Manufacturing Engineering
Perma-Anti-Skid Product Line

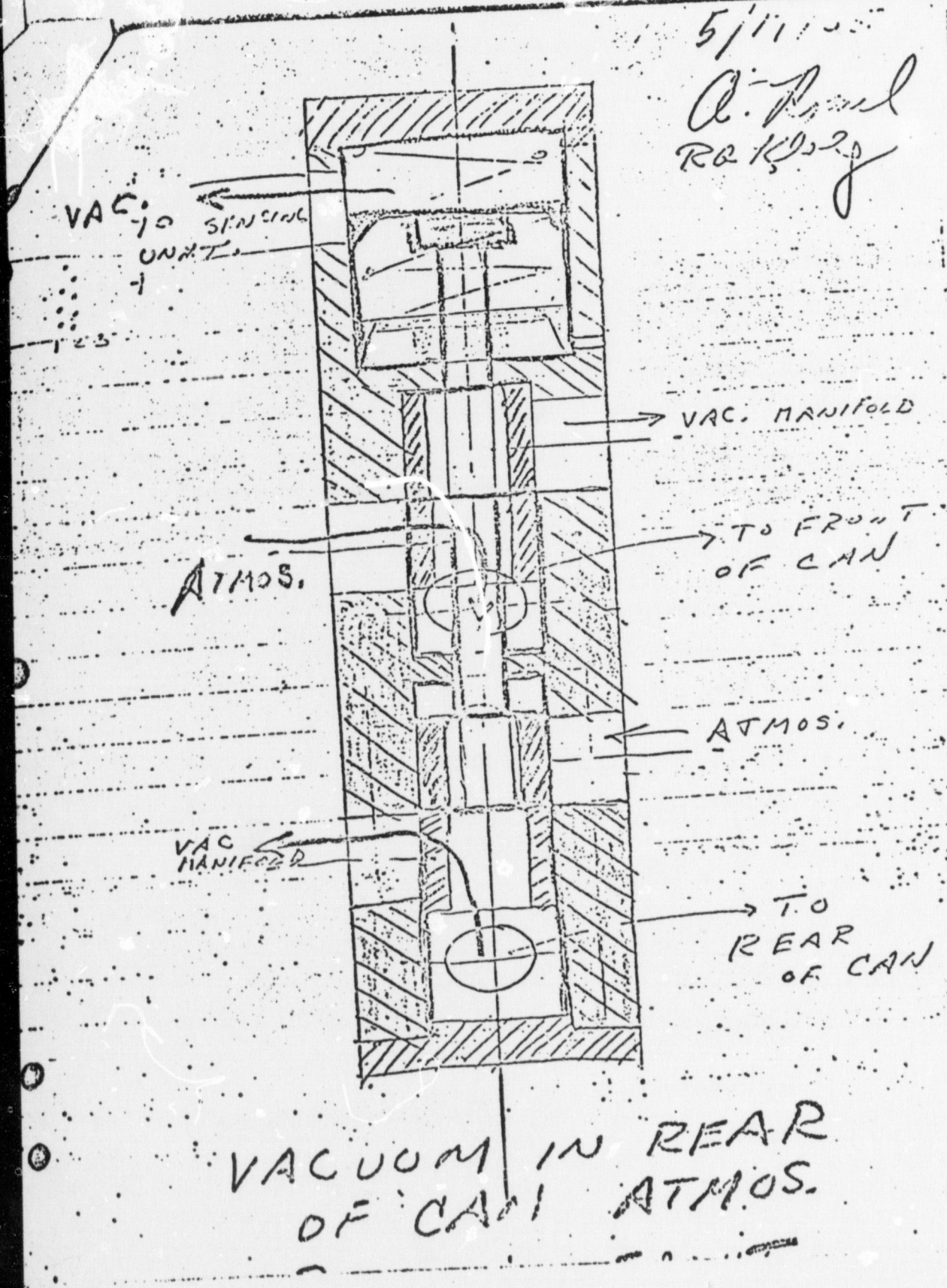
AR:ms
Encl.

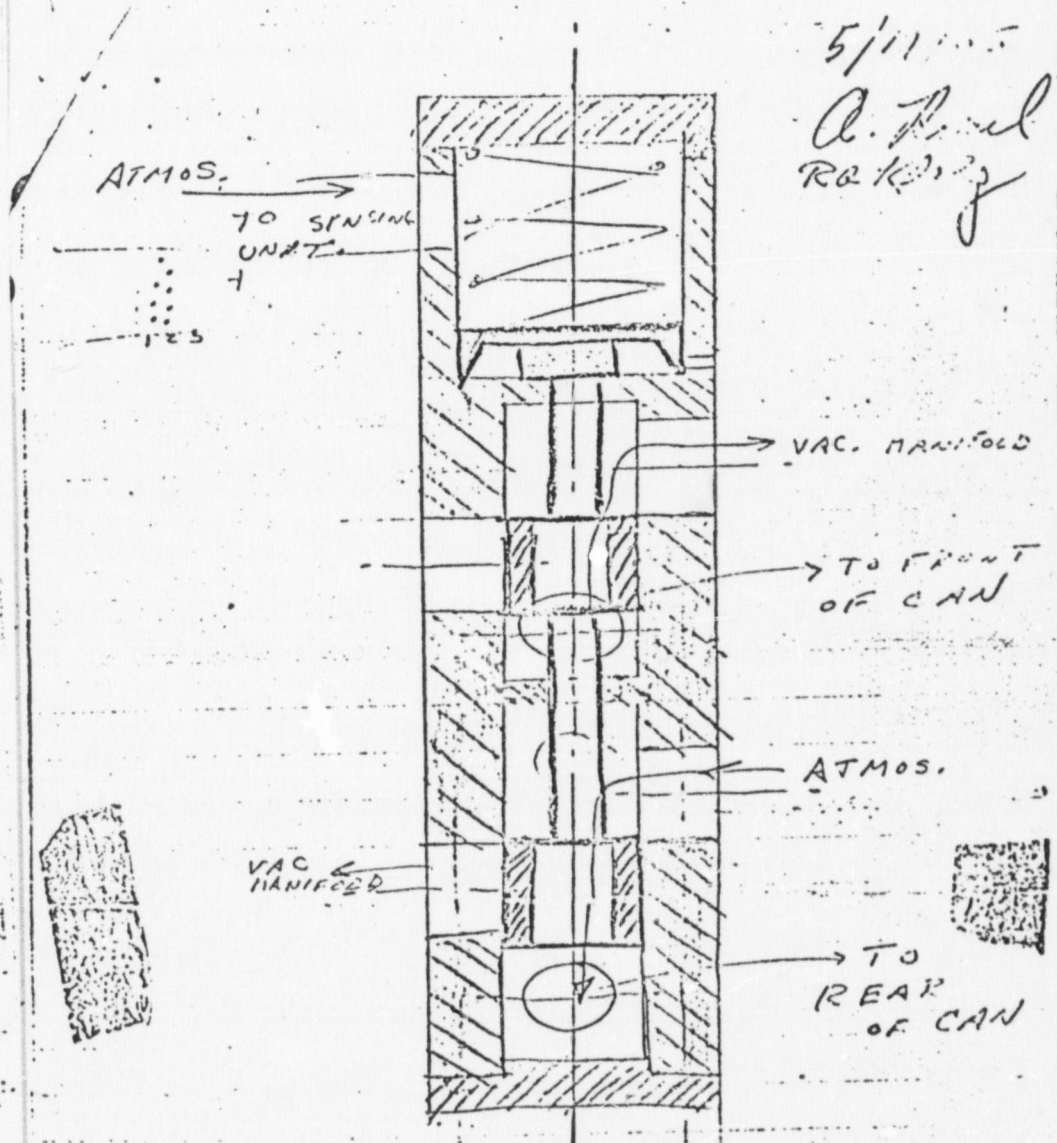
cc: Mr. R. A. Kloby

A. Revised


To Sensing unit
Front of Can
Exhaust
Vaculim supply
Rear. of Can

[PX 77, p 3]


5/11/...
A. Paul
RQ KD-2g
VAC. TO SENSING UNIT
VAC. MANIFOLD
TO FRONT OF CAN
ATMOS.
ATMOS.
VAC MANIFOLD
TO REAR OF CAN
VACUUM IN REAR OF CAN
ATMOS.



ATMOS. IN REAR OF CAN
VACUUM IN FRONT OF CAN.

MINIMUM FLOW AREA TO BE EQUIVACENT TO A 1/2" DIA. CIRCLE.

PLAINTIFF'S EXHIBIT 79

THE SINGER COMPANY

ELIZABETH PLANT • 921 FIRST STREET, ELIZABETH, NEW JERSEY • 201 EL 9-5200

RECEIVED
JUN 17 1965
MFG. ENG. DEPT. 39

June 16, 1965

Mr. Marshall Breen,
The Singer Company,
30 Rockefeller Plaza,
New York 20, New York.

Perna Antiskid Device - Design Changes

Dear Sir:

The Perna Antiskid Device has been altered to include a Vacuum Transfer Valve and an Hydraulic Flow Control Valve. The Transfer Valve is required to enable the Device to develop sufficient braking pressure to lock the wheels of certain model cars. The Flow Control Valve was added so that shorter stopping distances with the unit could be obtained.

Enclosed are:

1. Patent investigation submission form.
2. Letter from A. Ronel to E.A. Sprague dated 5/10/65 concerning the Transfer Valve.
3. Original sketches of Transfer Valve (5), dated 5/7/65.
4. Assembly sketch dated 5/10/65 showing Transfer Valve in relation to rest of the Device.
5. Print DC17-342639 of Transfer Valve.
6. A portion of a description of the Device which pertains to the Transfer Valve (pages 5 & 6).
7. A sketch dated 6/10/65 showing the Hydraulic Flow Control Valve and its location in respect to the automobile brake system and the Antiskid Device.

Yours very truly,

E. A. Sprague

E. A. Sprague, Manager,
Central Engineering Staff,
Manufacturing Division.

EAS/b

cc: Messrs. C. W. Brocker
R. Kleby

A. Ronel w/ submittal form
J. Wagner w/ submittal form

11 13

PLAINTIFF'S EXHIBIT 82

THE SINGER COMPANY

ELIZABETH, NEW JERSEY

M-13

July 7, 1965

Mr. C. C. Morehouse, Vice President
MARSH & MC LENNAN, INC. OF OREGON
Standard Plaza
Portland, Oregon 97204

Dear Mr. Morehouse:

The delays associated with shipment of your Anti-Skid Control are unfortunate but unavoidable.

After acquiring the patents to the control, a controlled marketing was started in the local area. Very frankly, some problems arose with regard to the function of the product. Most significant of these was a tendency for a lag or reduced braking at the end of the control cycle. It was found this was associated with the design of some of the 1965 braking systems. A modification to the unit was required and started at once. In the meantime, we had begun to pursue the automotive manufacturers for OEM application and product approval. Detroit requested a modification to the unit. They desired a greater output pressure from the control to answer two problems. First, a serious glazing or fading of brake linings would require higher output pressures that we offered. Secondly, with the trend toward disc brakes, greater output pressure was desirable.

The solution to both conditions required changes in the Powa-Vac section of the control. Redesign and modification was completed and a test program instituted. As is not uncommon, a new problem arose. Stopping distances with the control on dry roadway increased over those without the control. We certainly could not market the product without notifying our customers of this increased distance even if we did, under all conditions, give him steering control and reduced stopping distances except for dry roadway.

EXH. NO. ____
BORAK, REPORTER

We have tackled this problem and resolved it. The present unit being released for production does give equal or shorter stopping distances at all speeds in excess of 30 mph. At 30 mph you give up some stopping distance some of the time. Our test results at this speed were mixed. We feel the variables present as to road, tire and lining

11 243

(text of PX 82, p 1 transcribed on page E-541A)

After viewing all available copies of the preceding page, counsel for Appellant believes that said page reads as follows:

July 7, 1965

Mr. C. G. Morehouse, Vice President
MARSH & MC LENNAN, INC. OF OREGON
Standard Plaza
Portland, Oregon 97204

Dear Mr. Morehouse:

The delays associated with shipment of your Anti-Skid Control are unfortunate but unavoidable.

After acquiring the patents to the control, a controlled marketing was started in the local area. Very frankly, some problems arose with regard to the function of the product. Most significant of these was a tendency for a lag or reduced braking at the end of the control cycle. It was found this was associated with the design of some of the 1965 braking systems. A modification to the unit was required and started at once. In the meantime, we had begun to pursue the automotive manufacturers for OEM application and product approval. Detroit requested a modification to the unit. They desired a greater output pressure from the control to answer two problems. First, a serious glazing or fading of brake linings would require higher output pressures that we offered. Secondly, with the trend toward disc brakes, greater output pressure was desirable.

The solution to both conditions required changes in the Perma-Vac section of the Control. Redesign and modification was completed and a test program instituted. As is not uncommon, a new problem arose. Stopping distances with the control on dry roadway increased over those without the control. We certainly could not market the product without notifying our customers of this increased distance even if we did, under all conditions, give him steering control and reduced stopping distances except for dry roadway.

We have tackled this problem and resolved it. The present unit being released for production does give equal or shorter stopping distances at all speeds in excess of 30 mph. At 30 mph you give up some stopping distance some of the time. Our test results at this speed were mixed. We feel the variables present as to road, tire and lining

THE SINGER COMPANY ELIZABETH, NEW JERSEY

Mr. C. C. Morehouse - 2 - July 7, 1965

conditions make panic stops at this speed or slower difficult to compare on run-to-run. The average difference in stopping distance at these speeds on a variety of vehicles is less than 5% and, in most instances, is measured in inches.

We feel we have a product worthy of offering to the public and plan a full marketing campaign for September with limited production and sale starting within the next 3 to 4 weeks. If you desire, we can no doubt ship your unit prior to August 1st.

We hope this has helped to explain the delay and brings you up-to-date on the program status.

Yours very truly,

R. R. PATTEN
Manager
Factory Sales

rrp/dh

cc: Mr. J. Kelley

(text of PX 82, p 2 transcribed on page E-542A)

After viewing all available copies of the preceding page, counsel for Appellant believes that said page reads as follows:

Mr. C. G. Morehouse -2- July 7, 1965

conditions make panic stops at this speed or slower difficult to compare on run-to-run. The average difference in stopping distance at these speeds on a variety of vehicles is less than 5% and, in most instances, is measured in inches.

We feel we have a product worthy of offering to the public and plan a full marketing campaign for September with limited production and sale starting within the next 3 to 4 weeks. If you desire, we can no doubt ship your unit prior to August 1st.

We hope this has helped to explain the delay and brings you up-to-date on the program status.

Yours very truly,

R. R. PATTEN
Manager
Factory Sales

RPP/dk

cc: Mr. J. Kelley

PLAINTIFF'S EXHIBIT 88A

CO 340 (3-65)

MEMORANDUM

SINGER

30 ROCKEFELLER PLAZA • NEW YORK, N.Y. 10020

TO: Mr. A. di Scipio

FROM: B. C. Person, Chairman
Perma Anti-Skid Control Task Force

SINGER CONFIDENTIAL

DATE: August 10, 1965

REFER TO:

RECEIVED
AUG 11 1965
STANLEY BORISS

SUBJECT: SUSPENSION OF MARKETING AND WITHDRAWAL OF UNITS FROM FIELD - PERMA ANTI-SKID CONTROL

This memorandum presents (1) a recommendation that Singer-CPD undertake actions immediately to withdraw the Perma Anti-Skid Control units from the field and terminate our contracts with the three remaining distributors in the U. S., and (2) a plan for implementing this recommendation. Marketing of the units has been essentially suspended since March of this year, pending solution of technical deficiencies in the product.

This memorandum is not meant to be an interim report on the ultimate disposition of the Perma Anti-Skid Control program. The question of whether to proceed with development or to divest must await further technical and business evaluations (a visit to Cornell Aeronautical Institute is scheduled for August 10). The recommended actions are those that the Task Force feels should be taken as quickly as possible because of the existing exposures and the current technical status of the product.

Reasons for Recommendation

The costs for undertaking this program are high, but the reasons for doing so are compelling:

1. Legal Exposure: Approximately 184 units have been put on cars (in the U.S.) since Singer became involved with the product. If an accident should occur to one of these cars, Singer would be vulnerable to suit as the manufacturer of the device. We are aware of several limitations in these units (which are not of the current design): (1) stopping distances on dry ground are longer than if the device were not on the car; (2) the quality of certain components is such that there have been premature failures of the device; and (3) the design is not completely fail safe - varying losses of braking power, up to complete loss, can occur under different types of failure.

   Furthermore, recent newspaper articles indicate trial lawyers are becoming increasingly successful and interested in suing manufacturers, especially automobile manufacturers, under the "strict liability" doctrine.

D.PE #5
P.P.E-# 145

Reasons for Recommendation (continued)

2. Singer Name: The unfavorable publicity from an accident with a Perma Anti-Skid Control-equipped car could seriously damage the Singer reputation for quality, dependability, and integrity.

3. Business Responsibility: As a company of high integrity, Singer has responsibility both to its distributors and its customers to retrieve these units, which have been sold as safety devices, but have technical deficiencies.

4. Indefinite Development Period: Some of the deficiencies in the device discovered in the January-March period have been corrected, but the Elizabeth technical evaluation of the current design concludes the unit does not fully meet the criteria for reliability. An additional development period might range anywhere from three to twelve months. Because of this uncertainty as to when the unit will fully meet the criteria for reliability, retrieval of the existing units is recommended, not replacement.

5. Future Uncertain: Even with the current high public and government interest in safety, assuming the product can be fully developed, its future as an item to be made and sold by Singer is uncertain because of the nature of the product and the industry it is in. This product would place us in the automotive parts industry, which is dominated by the purchasing power and engineering skills of the Big Three. Secondly, the nature of the product, i.e., a safety device on automobiles, is distinctly different from any of our existing products and introduces a new dimension in our product liability risks. Thirdly, the patent protection is very specific, indicating that there is reasonable expectation that a group of automotive engineers could design around our patents and achieve the same end result. In fact, our Patent Department advises there. is a U. S. patent which accomplishes the same end result on a somewhat less "automatic" basis.

Particularly, because of the indefinite development period and the uncertain future of this unit as a Singer product line, we recommend terminating the distributor contracts. In view of these uncertainties, we do not believe it is wise to subsidize any of the distributors for interim periods.

Implementing the Recommendation

The plan developed for implementing our recommendation has a threefold objective:

1. Recover all field inventories and units now on cars in areas where Singer-CPD has liability exposure.

2. Terminate distributor contract with Monitor Enterprises, Inc.

3. Terminate contracts with two other distributors assumed when Perma device and components were purchased. The contract with Jandro was terminated in January, 1965.

Implementing the Recommendation (continued)

The strategy for terminating our contracts is somewhat different for Monitor than for the other distributors. The apparent interest of both Car Controls and Coulter in ending the contract and the nature of these contracts suggest they can be terminated without any costs above the cost of recovering the inventory. The Monitor contract is more complex; we need to find a mutually agreeable basis or face the possibility of legal action on their part.

The basic elements of our strategy are outlined below. We have included some steps in relation to Perma since the inventory related to Jandro (units on cars only), Car Controls, and Coulter was sold by Perma but made by Singer. Mr. Peacock, from Winthrop, Stimson, Putnam & Roberts, has advised us not to act unilaterally on this inventory.

Approach for Monitor

1. Seek a basis for terminating the contract with Monitor. Our objectives are:

   - Complete termination of contract and all claims, and assignment of any claims Monitor might have on Perma.
   - Assistance of Monitor in retrieving field inventories and units on cars.
   - Payment to be based on Monitor's recovery of reasonable expenses during period of Singer-Monitor contract; not on anticipated profits.

2. Employ J. Kelley, personally, at $10,000 to assist in recovery of inventory and, possibly, in any divestiture program.

3. Assign one member of Elizabeth Plant team to recover units.

Approach for Perma

1. Establish liability and responsibility of Perma on inventories in field.

2. Meet with Perma to get them to assume responsibility for inventories they sold and negotiate change in Singer-Perma contract. The desired changes are:

   - Eliminate reversion right clause.
   - Adjust royalty payment to recover cost of inventories in field.
   - Provide flexibility for Singer in regard to divestiture.

Implementing the Recommendation (continued)

Approach for Other Distributors

1. Take action on Jandro, Car Controls, and Coulter only.
2. Notify Singer (Canada) of our actions so they can handle O'Matic.
3. Call each distributor to arrange meetings.
4. Meet with distributors to set up plan for withdrawal. Key elements of the plan:
   - All correspondence done on distributor's letterhead.
   - Payment made on receipt of inventories in Elizabeth.
   - Termination of contract with Car Controls and Coulter.
5. Assign member of Elizabeth Plant team to recover units.

Publications

We have already obtained agreement that articles will be stopped in Women's Day, Reader's Digest, and Saturday Evening Post. An article will be carried in the October issue of Mechanics Illustrated. We have worked with their staff in changing the tone of the article from one that would give great publicity to Singer to an article of more general nature on anti-skid devices.

All letters to be used will be prepared by the Director of Advertising and Public Relations, in cooperation with B. F. Thompson, and all elements of our strategy will be reviewed with Winthrop, Stimson, Putnam & Roberts.

Exhibit 1 presents a summary of the major points of the Withdrawal Plan. Exhibit 2 presents an action plan for the Withdrawal Program.

Costs

It is estimated that the out-of-pocket costs for this unit removal and contract termination plan will total about $225,000. (See Exhibit 3.) Of this amount, $125,000 is the maximum we hope will be necessary to reach agreement with Monitor Enterprises, Inc. At the time we acquired the Perma device, we entered into an agreement with Monitor for them to act as our exclusive distributor in the U. S. The proposed termination cost is based on their recovering expenses incurred and does not reimburse them for loss of profits. Exhibit 4 shows an estimate of these expenses, based on their statement given to us on August 2, and adjustments we believe to be reasonable. The CPD Manager of Auditing has audited Monitor's books to confirm these figures.

Costs (continued)

An amount of $10,000 is proposed to retain Mr. Kelley as a consultant on retrieving the inventory. We believe his help is needed in this activity. Furthermore, we believe this will have more leverage than if it is included in the amount to the corporation (Monitor).

The inventories at Car Controls, Coulter, and Jandro are for devices sold by Perma and made by Singer. Our plan is to get Perma to assume responsibility for these costs; however, because of their financial position, we expect the actual out-of-pocket expenditure will have to be made by Singer and any recovery will be made in terms of revising the existing Singer-Perma contract.

Original Signed by
B. C. Person

Chairman, Perma Anti-Skid
Control Task Force
BCP:lk
Atts.
cc: Messrs. S. Boriss ← This copy for
R. H. Elman
J. E. McConnaughy
D. McKearnan
S. J. Murphy

Exhibit 1

SINGER CONFIDENTIAL

SUMMARY OF WITHDRAWAL PLAN

Objective of Plan

1. Recover all field inventories and units now on cars in areas where Singer-CPD has liability exposure.
2. Terminate distributor contract with Monitor Enterprises, Inc.
3. Terminate contracts with two other distributors assumed when Perma device and components were purchased.

Approach for Monitor

1. Seek a basis for terminating contract with Monitor. Our objectives are:
   - Complete termination of contract and all claims.
   - Assistance of Monitor in retrieving field inventories and units on cars.
   - Payment to be based on Monitor's recovery of reasonable expenses during period of Singer-Monitor contract; not on anticipated profits.
2. Employ J. Kelley, personally, at $10,000 to assist in recovery of inventory and, possibly, in any divestiture program.
3. Assign one member of Elizabeth Plant team to recover units.

Approach for Perma

1. Establish liability and responsibility of Perma on inventories in field.
2. Meet with Perma to get them to assume responsibility for inventories they sold and negotiate change in Singer-Perma contract. The desired changes are:
   - Eliminate reversion right clause.
   - Adjust royalty payment to recover cost of inventories in field.
   - Provide flexibility for Singer in regard to divestiture.

SUMMARY OF WITHDRAWAL PLAN

Approach for Other Distributors

1. Take action on Jandro, Coulter, and Car Controls only.
2. Notify Singer (Canada) of our actions so they can handle O'Malie.
3. Call each distributor to arrange meetings.
4. Meet with distributors to set up plan for withdrawal. Key elements of the plan are:
   - All correspondence done on distributor's letterhead.
   - Payment made on receipt of inventories in Elizabeth.
   - Termination of contracts (Car Controls and Coulter).
5. Assign member of Elizabeth Plant team to recover units.

Publications

The following magazines have agreed to stop articles:

Women's Day

Reader's Digest

Saturday Evening Post

We are working with Mechanics Illustrated to change the emphasis of the article in their October issue.

General

1. Letters prepared by Director of Advertising and Public Relations and reviewed with B. F. Thompson.
2. Determine how to handle customer that may not relinquish anti-skid unit.
3. All letters and strategy reviewed with Winthrop, Stimson, Putnam & Roberts.

lcv
8/10/65

Exhibit 2

SINGER CONFIDENTIAL

ACTION PLAN FOR WITHDRAWAL PROGRAM PERMA ANTI-SKID CONTROL

Steps	Individual Responsible	Target Date
A. MONITOR		
1. Outline project to J. Marusak	B. C. Person	Complete
2. Have J. Marusak audit Monitor's books	B. C. Person	Complete
3. Develop specific offer to Monitor	Task Force	8/10
4. Review offer and strategy with Peacock	B. C. Person	8/10
5. Clear offer and strategy with A. di Scipio	B. C. Person	8/10
6. Hold meeting with J. Kelley et al	B. C. Person S. Boriss R. H. Elman	
7. Prepare letter for customers	T. Royal	8/11
8. Select Elizabeth personnel to work with J. Kelley	B. C. Person S. J. Murphy	8/11
9. Prepare weekly report on progress of withdrawal program	Individual assigned from Elizabeth	
B. OTHERS		
1. Have letter prepared for customer (same as Step A-7)	T. Royal	8/11
2. Develop approach to PERMA: - Confirm amount of money involved - Outline approach in conference - Have revised contract prepared	B. C. Person S. Boriss	8/10
3. Have Peacock review: - Strategy with Perma - Strategy with distributors	B. C. Person S. Boriss	8/10
4. Call Jandro, Coulter, Car Controls	B. C. Person	8/13
5. Select Elizabeth personnel to work with distributors in Step 4	B. C. Person	8/11
6. Meet with Perma	B. C. Person S. Boriss	8/13
7. Hold meeting with each distributor	B. C. Person S. Boriss Elizabeth Personnel	8/13
C. Carry out withdrawal program and prepare weekly reports	Elizabeth Personnel	

SINGER CONFIDENTIAL

ESTIMATED COSTS OF WITHDRAWING UNITS FROM THE FIELD AND SUSPENDING MARKETING

Exhibit 3

Estimated Costs

			Out-of-Pocket
A. Monitor			$125,000
	Cost to terminate contract		30,472*
	Inventory		5,000
	Cost to remove units from cars		
	Use of Kelley as consultant in removal program		10,000
			$170,472

	Inventory	Removal Cost	Total
B. Other Dealers	$28,106	$ 1,250	$ 29,356
Car Controls	16,139	1,250	17,389
Coulter	960	400	1,360
Jandro	$45,245	$ 2,900	$ 48,145

C. Warehouse and Freight	$ 3,000
TOTAL (ROUNDED)	$221,617**

* Excludes inventory held by Monitor, but not paid for, $56,010. Accounts receivable at Elizabeth will be reduced by $56,010 and their inventory increased by the same amount. Actual write-off depends on outcome of the program.

** Plus the time for two people from Elizabeth for 2-3 months.

SINGER
CONFIDENTIAL

ESTIMATE OF MONITOR'S NET EXPENSES

JANUARY 1 - JULY 31, 1965

Exhibit 4

Monitor's summary of expenses to May 31, 1965		$118,750
Our estimate of deductions:		
Officers' Salaries	$10,000	
Contingent Loss	5,000	
Interest	1,950	
Rent	1,500	
	$18,450	
Our estimate of net expenses, January 1 - May 31, 1965		$100,300
Monitor's summary of expenses, June 1 - July 31, 1965		$ 26,000
Our estimate of deductions:		
Cost of removing units	$ 4,000	
Sales payroll and administration	4,000	
	$ 8,000	
Our estimate of net expenses, June 1 - July 31, 1965		$ 18,000
Our estimate of total expenses, January 1 - July 31, 1965		$118,300
Less estimate of net income to Monitor for sale of units *		12,000
Our estimate of net expenses less income, January 1 - July 31, 1965		$106,300

* Excludes units sold by mail.

DC
8/3/65

PLAINTIFF'S EXHIBIT 89

RECEIVED
AUG 16 1965
BURTON C. PERSON

SINGER
30 ROCKEFELLER PLAZA • NEW YORK 20, N.Y.

MEMORANDUM

TO: Mr. B. C. Person

FROM: David McKearnan

DATE: August 16, 1965

REFER TO: DMcK/jm

SUBJECT: PERMA

The purpose of this memorandum is to discuss a number of alternatives that might be available should the decision be made to divest of all or part of Singer's interests in the Perma Anti-Skid Device.

It is difficult at this time to make an intelligent assessment of the possibilities of successful divestment because we do not know what we have to sell. The Perma Anti-Skid Device has not been developed to the point where the product can be manufactured and marketed as a safety device. It is understood that a program is currently under way to determine the design feasibility and functionability of the product in its present state and what design, engineering, and testing work must be done to bring it to a point where a full scale manufacturing and marketing effort could be launched.

The range of alternatives available now cover a broad spectrum and will be critically influenced by the results of this program. On the one hand, if the basic design of the Perma Device were suspect in terms of its ultimate ability to function as a valuable safety device, it will be difficult to salvage more than a small portion of our investment. Certainly many questions will be raised in the minds of perspective buyers due to our own inability to bring our design and engineering work to successful conclusion and, even to a greater degree, by the program to recall to the factory all units that have been shipped. On the other hand, if it turns out that the device in its present configuration is a true safety aid to automobile braking systems and that only small additional expense need be incurred to bring it to a completed state, then our position may be of much greater value and all or a large portion of our investment may be recoverable. In either case, it should be recognized that the ultimate market potential of an effective anti-skid device has not been demonstrated. A purchaser of the Singer's position would

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therefore, have to take into account two areas of significant risk: one concerning design, engineering, and manufacture; and the other concerning marketability.

The major portion of Singer's investment in Perma is tied up in inventory which is on the books at $1,300,000. If the design is proven and the prospective buyer believes that the product can be marketed successfully, this inventory could have full or nearly full value to the buyer. The same can be said for the $210,000 of advance royalties that have been paid to Perma Research and Development Company. It will be more difficult to recover the $190,000 of engineering costs that Elizabeth has expensed. It is highly doubtful that any purchaser would pay for the approximately $185,000 in costs that will be incurred to remove the Singer manufactured Perma Devices from the field and to terminate the contract with Monitor. Thus, under even the best circumstances, it probably will not be possible to sell the Perma interests for an amount approaching Singer's investment of $1,900,000.

In view of the current uncertainties with regard to the product itself, efforts to develop divestment alternatives are largely "blue sky". In the event that Singer's interests are saleable, however, the divestment deal might be structured in one of the following forms:

1) Cash sale - Singer's Perma inventory plus all rights to Perma patents as well as our know-how would be sold in "as is" condition for a flat cash payment to be made at the time of the closing.

2) Down payment plus term notes - A significant down payment, say 20% to 40%, would be made plus serial term notes payable over the course of 2 to 5 years.

3) Down payment plus contingent payments in one of several forms:

   a) Payments as inventory is sold - Since the major portion of that which we would be selling is in the form of inventory, it would seem reasonable that the purchaser pay Singer as he sells that inventory. In this manner, we could sell the inventory at a given amount per unit receiving say 25% of the total value down and 75% of the unit value as the units are sold.

b) Royalties - After a down payment, a fixed or percentage royalty would be paid to Singer as the devices are sold. In view of the royalty payments for which Singer is already committed to Perma, it may be difficult to impose additional royalties. Also, inventory payments would more truly reflect the nature of any proposed deal.

4) Marketing Agreement - Singer could continue to manufacture Perma Devices and could seek a marketing agreement with a company in the automobile parts business. This type of arrangement would have many of the same disadvantages as are now inherent in Singer's Perma activities as they are now being conducted, especially in the area of product liability.

5) Joint Venture - Singer could seek an automobile parts company with which to form a new company as a joint venture for the conduct of the Perma business. Again, the same disadvantages are present as in No. 4.

In all of these cases, the down payment as well as term notes or contingency payments could be in the form of common stock or some other security.

Since our divestment would be based largely on inventory value rather than on a going concern basis, our interests probably must be sold to a company that is already in the automobile parts business rather than a company seeking diversification. In the opinion of the writer, Perma devices could be marketed most successfully by a firm that controls its own retail outlets and, thereby, the ultimate installation on the customer's automobile. This is in contrast to the traditional automobile parts distributor who sells through a two or three level distribution system to independent garages and service stations.

The following companies seem to be the most likely prospective purchasers of Perma:

1) Gulf and Western Industries, Inc.
2) Maremont Corp.
3) Midas International Corp.
4) Rayco Manufacturing Co. (A subsidiary of B. F. Goodrich Company)

5) Detroit Gasket and Manufacturing Co. (A subsidiary of Indian Head Mills, Inc.)
6) Divco-Wayne Corp.
7) Standard Products Co.
8) Bendix - Westinghouse Automatic Air Brake Co.
9) Curtis-Wright Corp.
10) Mack Trucks, Inc.
11) Firestone Tire and Rubber Co.
12) General Tire and Rubber Co.
13) Associated Spring Corp (A subsidiary of Bowman Products Co.)
14) American Brake Shoe Company
15) Borg-Warner Corp.

It would be desirable to limit the conduct of active negotiatious to two or three prospective purchasers so as not to give the impression of a panicked or distressed sale. Also it may be best to use the services of a professional deal broker in approaching most of these companies.

As soon as the various technical evaluations of the Perma Device have been completed, it will be possible to develop a divestment program in more specific form. At the same time, the range of acceptable selling prices and terms can be decided upon.

DWdC

c.c. Mr. C. F. Bruder
Mr. W. N. Dawes
Mr. R. H. Elman
Mr. S. Boriss

PLAINTIFF'S EXHIBIT 90A

LCP

SINGER

30 ROCKEFELLER PLAZA • NEW YORK 20, N.Y.

MEMORANDUM

TO: Mr. D. P. Kircher

FROM: D. D. Marsden

DATE: August 30, 1965

REFER TO:

SUBJECT: Status Report — Perma Anti-Skid

I am attaching a status report developed by Mr. Torello pertaining to the Perma Anti-Skid program.

We have arranged for Elizabeth to furnish a financial status report each month comprised of the schedules shown in the attached report under Exhibits 1 and 2.

D. D. Marsden

cc: C. F. Druder
A. di Scipio
L. E. Hough

RECEIVED
AUG 30 1965
Alfred di Scipio

PERMA ANTI-SKID

STATUS REPORT AND RECOMMENDATIONS

The development and marketing effort associated with the Perma anti-skid device has been temporarily discontinued by the Consumer Products Division. An initial review, conducted by CPD Management shortly after they became responsible for the Perma program, indicated that this device did not meet the reliability and quality standards expected of a Singer product and required in a braking device. Further, because of the possible legal exposure, CPD is in the process of recalling all units from the field. It is the Division's intention to obtain an independent technical evaluation of the anti-skid unit at its presently developed stage. Cornell University's testing laboratories have been asked to submit a testing proposal to determine the technical validity and reliability of the device.

The Elizabeth-Perma people now believe that the presently developed unit meets the performance criterion of anti-skid control under a panic braking situation. In addition, their limited tests on a 1965 Cadillac using a dual piston braking unit indicate that the average stopping distance using the Perma device is about equal on dry pavement to an auto without the device. On wet road surfaces, the average stopping distance with the unit is shorter at all speeds and substantially shorter (5% to 8%) at speeds of 50 m.p.h. and higher. Tests conducted on a 1965 Buick and 1964 Dodge with single piston units showed similar results to those obtained on the 1965 Cadillac and the dual unit.

There still exist certain problems relating to the device that can effect its reliability.

- The loss of vacuum due to vacuum hose breakage or engine stall out can leave the driver with less than adequate braking capability. However, a similar instance to the effects of this problem also exists during engine stall on cars equipped with power brakes and no Perma device.

  Associated with the engine stall problem would be that the anti-skid unit is not fail safe. Should the valve on the Perma unit jam in an open position, the driver would encounter a complete loss of braking power during a panic stop. The Elizabeth-Perma people feel that this is a very remote probability, similar to a complete loss of brakes without the Perma unit. However, based on engineering evaluations made by E. I. Dupont in 1964, there are also a number of other areas where the unit can fail and cause a complete loss of braking power.

- Occasional slight lags during the last cycle of the unit in a panic stop have been recorded on the oscillograph.

- The unit has not been tested under actual driving conditions when exposed to an extreme environmental situation (heat, cold, dust, snow, etc.).

- The unit has not been tested under extensive use in actual driving conditions.

In addition to the current limitations on the presently developed product, other problems exist relative to further development of the unit.

- None of the 1936 model cars have been tested nor has any information been obtained to date which would permit any prototyping work to begin. New automobile model introduction would be a continuing problem with the present Perma device.

- Tests of the presently developed unit have only been completed on certain model cars. Elizabeth believes that tests to date would indicate that the unit can be expected to perform similarly on untested autos. However, since each model has certain unique characteristics, these models should also be tested before any decision is reached on the utility value of the device.

- The presently developed unit is not applicable on cars utilizing a disc braking system. Use of the disc brakes on autos has been an increasing factor in the market and could affect the potential Perma market if Cadillac switches to disc brakes for their 1936 models. Elizabeth believes that the present unit can be adapted to disc brakes but further information through experimentation and testing is required.

Since the unit does not presently meet the criteria for reliability, CPD intends to engage Cornell University for testing of the unit. Should their technical evaluation be favorable and indicate that the unit performs a useful function and a greater degree of reliability can be developed, several alternatives exist for the CPD.

Alternative A

Reinstate development work to obtain a degree of reliability and shorter stopping distances on dry pavements. Following this, Singer could

1) sell the complete product line to another company,
2) market the product until present inventory has been depleted, or
3) market the product on a long-term basis with the objective of continuing in the business once the present Perma inventory is depleted.

Alternative B

Do not commit additional development funds for this project. Singer then could

1) write off and attempt to sell at scrap value the present Perma commitment,
2) attempt to sell the present Perma inventory to another company,
3) develop a marketing program for the presently developed product with a minimum of additional product development expense.

All of the previous alternatives and sub-alternatives are based on a favorable evaluation by the Cornell Laboratories. If Cornell should give an unfavorable report on the present and projected technical capabilities of the product, then Singer would probably be required to take a write-off approximating the size of the total Perma commitment ($1,786,400 excluding the $232,000 loss to 6/30/65 as outlined on Exhibits 1 and 2.) It would appear doubtful that a prospective outside purchaser for the Perma inventory could be found if the results of an unfavorable technical evaluation were made known to him.

From a product line point of view, the Perma business does not appear to fit in with Singer's basic business nor does it appear to be a good base for further expansion into the automotive parts and accessories field. CPD has also indicated that they do not feel this is a logical or attractive business for them over the long run. Also, to attempt to sell the device at its presently developed stage to end customers would create possible lawsuits in case the Perma units malfunction. These factors would seem to indicate that alternatives A-3 and B-3 (i.e., continue to market the device on a long-term basis) would both be undesirable courses of action. No, because of product liability

Alternatives A-2 and B-3 would appear on the surface to be a reasonable method of disposing of the Perma inventory if 50,000 Perma units could be sold at the retail level and the device were technically acceptable. However, there are service and marketing considerations that make this alternative undesirable. Once the 50,000 units are sold, Singer would have to contend with the following factors:

a) Termination of distribution contracts.

b) A stockpile of spare parts for possible replacement purposes.

c) The establishment of service facilities for the device even though production of the device would be discontinued.

d) The possibility of a significant additional marketing expense that would be at risk if unit sales did not materialize. The size of this possible expense would be related to the buyer's resistance encountered at the retail level.

e) A large amount of ill will toward Singer generated by the purchasers of the device due to possible lack of service and replacement parts.

f) A great deal of time and effort on the part of Elizabeth and CDP management would be spent on a product line that would not be contributing toward Singer growth in the future.

From the preceding analysis, it would appear that sale of the Perma inventory and other Perma assets to another operating company would be the desirable alternative for Singer. It would avoid the problems and considerations associated with the other four sub-alternatives. The possibility of selling Perma without further development work exists if the Cornell tests are favorable (Alternative B-2). However, a prospective purchaser may not want to pay Singer's book value tied

up in the Perma operations since he probably would need to expend further amounts for research and development to improve product reliability. Required improvements through research and development may obsolete a major portion of the components used in the Perma device. If it is felt that a reasonable dollar amount of additional development work would improve the performance and technical reliability of the Perma product, a price closer to book value could probably be obtained by Singer upon sale of the Perma operations. The Elizabeth-Perma people estimate a long-range program of 9 to 12 months could develop a device that would be less dependent on the performance of vehicle systems and that would be tested for environmental and endurance factors. Development of a fail-safe capability whereby component malfunction reverts the braking system back to normal braking power would not be achieved through this limited program. The cost of the program would be as follows:

$ 50,000	(Low Pressure Problem and Vacuum Failure)
150,000	(Manpower)
100,000	(Test Truck)
55,000	(Environmental Test)
$355,000	Total

This course of action would not be desirable unless prospective purchasers offered a very low price for the present Perma operations and that the proposed further development work would produce an acceptable device within the projected time. The additional purchase price to be obtained due to further development work should be at least $400,000 and probably $800,000 to $1,000,000 higher than the sale of the Perma operations in their presently developed state. If this does not appear highly probable, it would be more desirable to sell the unit in its presently developed state to another company or liquidate the inventory for scrap value. One advantage of selling Perma in its presently developed state would be that Elizabeth and CPD management time would be freed from this nonproductive operation.

It should be noted that CPD anticipates possible legal problems should they sell the presently developed product line to another party without a specific liability release clause. The Division also believes that with a specific liability release clause, the probability of sale to another company is very low. In addition, the CPD anticipates the possibility of bad publicity should some of the units malfunction even though Singer would not be liable for the malfunction.

One problem exists relative to sale of Singer's Perma operations. The contract with Perma for purchase of patent rights contains a reversion clause. This clause basically states that unless the buyer (Singer) expends $100,000 for marketing, promoting and advertising the product, during calendar 1966 and each year thereafter, the Perma patents and all tools for the Perma operations revert back to the Perma Research and Development Corporation for a payment approximating $50,000. This clause would have to be changed through negotiation with Perma in the event of possible sale to a prospective purchaser.

Exhibits 1 and 2 detail the Perma investment and the results of the Perma operation to date. Explanations and details of the commitment are part of Exhibit 1. Elizabeth will continue to develop these status reports on a monthly basis as long as Singer is involved in the Perma operations.

R S Torello

R. S. Torello

RST/vl

Attachments

August 27, 1965

Exhibit 1

PERMA PRODUCT LINE

MONTHLY STATUS REPORT

($000's)

	1964 Results* (Full Absorption Basis)	6 Months to June 30, 1965* (Variable Cost Basis)
Net Sales	$ 37	$. 58
Standard Cost	43**	34
Margin at Standard Cost	(6)	24
Manufacturing Variance - Fav.(Unfav.)	(20)	(60)
Inventory Adjustment - Fav.(Unfav.)	-	(20)
Margin at Actual Cost	(26)	(56)
Variable Selling & Administrative Expen	-	-
Variable Margin	(26)	(56)
Period Costs:		
Manufacturing	-	107**
Idle Plant	-	-
Selling	-	-
Research & Development	-	-
General & Administrative	-	32**
Total Period Costs	-	139
Operating Income	(26)	(195)
Other Income/Other Expense (Net)	-	(11)
Net Income Before Tax	$(26)	$(206)

* Entered Contract with Perma June 1964
** Includes Both Specific and Assigned Costs

Exhibit 2

PERMA ANTI-HALO DEVICE

INVESTMENT AND COMMITMENTS AS OF JUNE 1965

Inventory and Purchase Commitments		
Opening Inventory Balance 1/1/65	$ 844,000	
Add: Purchases	374,000	
Labor and Overhead	6,000	
	1,224,000	
Less: Cost of Goods Sold	34,000	
	1,190,000	
Valuation Reserve	20,000	
Net Book Value of Inventory	1,170,000	
Purchase Commitments	67,000	$1,237,000
Fixed Assets Acquired or Committed (Schedule A)		
Gross Asset Value	$ 24,400	
Accumulated Depreciation	2,000	
Net Book Value		22,400
		210,000
Prepaid Royalty Expense		
(Refer to Exhibit 2 of the Perma Contract and the application of royalty payments on Page 5.)		
Cost of Suspending Marketing and Withdrawal of Units From Field (Person's letter of 8/6/65 to di Scipio)		
Termination of the Monitor Contract	$ 85,000	
Cost of Retrieving Units in the Field	90,000	
Cost of Retaining Kelly of Monitor as a consultant on retrieving inventory	10,000	
Singer Account Receivables from Monitor	56,000*	
Travel and Other Expense of Retrieval Program	10,000	251,000
Other Assets or Commitments		
Unamortized Technical Services (Originally $49,000)	$ 23,000	
Purchase Order Termination Cost (Change in Part Design)	43,000	66,000
TOTAL		$1,786,400

* This amount would be subject to a reduction for any recovery that could be made from Perma Research and Development Company.

FIXED ASSETS - PERMA DEVICE

AS OF JUNE 1965

Description	Gross Asset Value	Net Book Value 6/26/65
Test stand and fixture for testing Perma-Vac Anti-Skid Device Sensing Unit	$ 4,713.35	$ 4,325.21
Build test stand and fixture for Perma-Vac Unit	4,530.34	4,152.88
Build test stand for Perma-Vac Anti-Skid Device Pressure Switch	3,051.36	2,792.12
Anti-Skid Recording Oscillograph	5,940.80	5,693.27
Test vehicle for road testing Anti-Skid Device	4,900.00	4,287.50
1 - Acro Leaf Model 250 H Hot Stamping Press	1,234.55	1,183.11
	$24,375.40	$22,434.09

1. Inventory values are stated on a direct cost basis. The inventory balance prior to the acquisition of the Perma Corporation's inventory and assumption of their liabilities was approximately $300,000 at 10/31/64.

2. Fixed Asset value pertains only to those capital assets purchased directly for the Perma commitment. The amount shown does not include general purpose machines and other fixed assets used in the Perma program that were at Elizabeth before the Perma commitment was made or that are presently being used in other operations.

3. Prepaid Royalty Expense is an asset created by Singer's assumption of the Perma Research and Development Corporation's liabilities. The contract signed with Perma states that royalties would be due to Perma on the basis of $10.00 per unit for the first 21,000 units sold. Singer would forego payment of royalties on the first 21,000 units and the prepaid royalty would be amortized by Singer as the first 21,000 units were sold.

4. Cost of Suspending Marketing and Withdrawal of Units in the Field.

   a) Termination of Monitor Contract - CPD has negotiated an agreement with Monitor, the national distributor of the Perma device, to terminate the present distribution agreement. The $85,000 settlement represents a portion of the expenses incurred by Monitor in the preliminary promotion of the Perma device. During the period that these expenses were incurred by Monitor, Singer did not allow additional units to be sold to end customers.

   b) Cost of Retrieving Units in the Field - Most of the units in the field are held by Monitor and their sub-distributors. It is Singer's intention to take back these field units regardless whether they were Perma manufactured or Singer manufactured units.

   c) Cost of Consultant - Singer has reached an agreement with Kelly, the head of Monitor, to be in charge of the retrieval program at a cost to Singer of $10,000.

   d) Travel and Other Expense - A cost of the retrieval program will be about $10,000 for travel and associated expenses.

   e) Singer Accounts Receivable from Monitor - Singer sold a number of units to Monitor during 1965 which were placed in the Monitor warehouse. These units were sold on a credit basis. Should Singer liquidate their Perma operations, Monitor would in all probability not be able to settle this account with Singer. This amount is listed separately rather than included as part of the cost of the retrieval program.

... continued...

5. Other Assets or Commitments

a) Unamortized Technical Services - As part of the original Perma contract, Singer agreed to engage the Perma Research and Development Corporation as technical consultants at approximately $3,000 a month for 6 months. With the exception of the last $6,000 payment, the $29,000 fee has been paid and is being amortized over the 12 months of calendar 1965. $23,000 represents the unamortized portion of this payment at 6/30/65.

b) Purchase Order Termination Cost - After the acquisition of the Perma inventory from the Perma Research and Development Corporation, certain design changes were made on the Perma anti-skid device. Since these changes made certain parts obsolescent for which there were certain purchase order commitments outstanding, Elizabeth will incur an expense of about $43,000 to cancel these commitments.

(paragraph 5.(a)of PX 90A, p 11 is transcribed on page E-567A)

After viewing all available copies of the preceding page, counsel for Appellant believes that the first paragraph thereof reads as follows:

> "a) Unamortized Technical Services - As part of the original Perma contract, Singer agreed to engage the Perma Research and Development Corporation as technical consultants at approximately $8,000 a month for (6?) months. With the exception of the last $8,000 payment, the $49,000 fee has been paid and is being amortized over the 12 months of calendar 1965. $23,000 represents the unamortized portion of this payment at 6/30/65."

PLAINTIFF'S EXHIBIT 92

RECD SEP 13 1965

THE SINGER COMPANY

THIRTY ROCKEFELLER PLAZA · NEW YORK 20, NEW YORK

CONSUMER PRODUCTS DIVISION

8 of & 26-A filed 11-12-70 SS

September 9, 1965

Perma Research and Development Company
345 East Washington Street
North Attleboro, Massachusetts

Attention Mr. F. Perrino, President

Gentlemen:

This will confirm the conversations which took place at a meeting at your offices on August 30, 1965, at which the writer and Mr. Dorios were present on behalf of The Singer Company and Messrs. Perrino, DiBenedetto, Krawczyk, Karp and Mainelli were present on behalf of Perma.

We appreciate very much the cordial treatment we received from Perma, and the friendly atmosphere in which the discussions took place, but we would like to make it entirely clear that we are faced with a most serious situation arising out of our contract dated December 21, 1964.

As we told you, it has become necessary for us to recover from the dealers listed in Schedule A of Exhibit 1 of such contract their inventory of the product and further to recover the product from the hands of users. In one case it has been necessary for us to compensate a distributor for various promotional and operational expenses. We regard these expenses as arising out of breach of representations and warranties on your part and further out of your failure to disclose pertinent information. We take the position that you are obliged to indemnify us in this respect. The total amount of our damages cannot yet be fully assessed, but we will keep you informed of our position in this respect; in light of developments subsequent to Mr. McDonald's letter to you of June 22, 1965, such damages are clearly greater than the amounts mentioned therein.

We would further like to confirm our discussions to the effect that such recovery effort is being taken to minimize our damages. We also hope to establish whether it is feasible to modify the product so that it is marketable. To this end we propose to procure the evaluation of a qualified, independent laboratory and have in fact initiated discussions with the Cornell Aeronautical Laboratory of Buffalo, New York.

D-504

Also, if the occasion arises when the assistance of Mr. Perrino becomes appropriate to this effort, we will let you know. In this respect Mr. Perrino's assistance would be called for pursuant to his letter agreement with us dated December 21, 1964.

The remedial action which we have outlined above is being undertaken without prejudice to any of our rights or remedies in the premises, including the right to indemnification.

Very truly yours,

B. C. Person
Director of Technical Services

BCP:lk
cc: Mr. T. P. Peacock - Winthrop, Stimson, Putnam & Roberts

PX 94, p. 1

FAIL-SAFE DESIGN DEFICIENCIES OF FERRA ANTI-SKID DEVICE

Description of Failure Which Causes Loss Of Braking Power	Description of Brake Power Failure	Possible Design Alternatives	Effect Of Design Change On Present Inventories	Remarks
1. Complete loss of vacuum due to engine stall-out or hose breakage	Brake power availability reduced to less than half of the recommended minimum	a. Provide vacuum reserve tank	a. No	a. It appears that reserve tank sufficiently low enough to provide vacuum for a 60 m.p.h. controlled stop would create installation problems. This change would also increase the manufacturing cost about $10.00 per unit. Installation time and cost would also increase.
		b. Major redesign of Ferra-Vac Unit:	b. 90% of Ferra-Vac would be scrapped. It is hard to determine the extent of changes needed on Sensing Unit without having the benefit of preliminary design layouts and calculations	b. Design calculations based on engine performance data limiting factor be made to determine whether desired results can be obtained
		1. Decrease bore size		
		2. Increase stroke		
		3. Increase container diameter		
		4. Change spring and other parts		
		5. Increase fluid flow rate		
		Item 5 may involve changes in Sensing Unit		

PLAINTIFF'S EXHIBIT 94, PAGES 3-5

(the last column of PX 94, p 3 is transcribed on page E-570-A)

After viewing all available copies of the preceding page, counsel for Appellant believes that the last column thereof reads as follows:

> "a. It appears that reserve tank sufficiently large enough to provide vacuum for a 60 m.p.h. controlled stop would present installation problems. This change would also increase the manufacturing cost by about $10.00 per unit. Installation time and cost would also increase.
>
> b. Design calculations based on engine performance data limiting factor be made to determine whether (desired?) results can be obtained."

Description Of Failure Which Causes Loss Of Brake Power	Description Of Brake Power Failure	Possible Design Alternatives	Effect Of Design Change On Present Inventories	Remarks
Reduction of engine vacuum during cycling	Partial loss of braking power at end of cycle. Usually occurs at speed of 15 m.p.h. and results in longer stopping distances	a. Same as 1.-a b. Same as 1.-b		
Speed position relationship of governor and rotary valve inconsistent with locking pressure required for given vehicle speed and road coefficient of friction	Same as above	a. Major redesign of Sensing Unit and drive train	a. Sensing Units and drive components obsoleted	This limitation has not [illegible] act. A theoretical possibility which is being investigated. It should be noted that the [illegible]ging could be attributed to either or both items 2 and 3
Jamming of rotary valve in vacuum position	Total loss of brake power at any speed	a. Provide stronger solenoid return spring. Solenoid coil must be wound to generate enough magnetic power to overcome spring selected	a. Solenoids would be obsolete	
		b. Change valve design from rotary to linear motion	b. Sensing Unit would be ob[illegible]ated. 50% of comp[illegible]nts scrapped	If this major redesign were undertaken, we should also make the changes in alternate "a"

[PX 94, p 4]

E-571

[PX 94, p 4]

Description Of Failure Which Causes Loss Of Braking Power	Description Of Brake Power Failure	Possible Design Alternatives	Effect Of Design Change On Present Inventories	Remarks
Reduction of engine vacuum during cycling	Partial loss of braking power at end of cycle. Usually occurs at speed of 15 m.p.h. and results in longer stopping distances	a. Same as 1.-a b. Same as 1.-b		
Speed position relationship of governor and rotary valve inconsistent with locking pressure required for given vehicle speed and road coefficient of friction	Same as above	a. Major redesign of Sensing Unit and drive train	a. Sensing Units and drive components obsoleted	This limitation [illegible] not [illegible] ject. [illegible] vestigated. It should noted that the [illegible] could be tributed to either both 1 [illegible] 2 and 3
Jamming of rotary valve in vacuum position	Total loss of brake power at any speed	a. Provide stronger solenoid return spring. Solenoid coil must be wound to generate enough magnetic power to overcome spring selected	a. Solenoids would be obsolete	
		b. Change valve design from rotary to linear motion	b. Sensing Uni would be ob [illegible]ted. 50% of comp [illegible]nts scrapped	If this major redesign were undertaken, we should also make the changes in alternate "a"

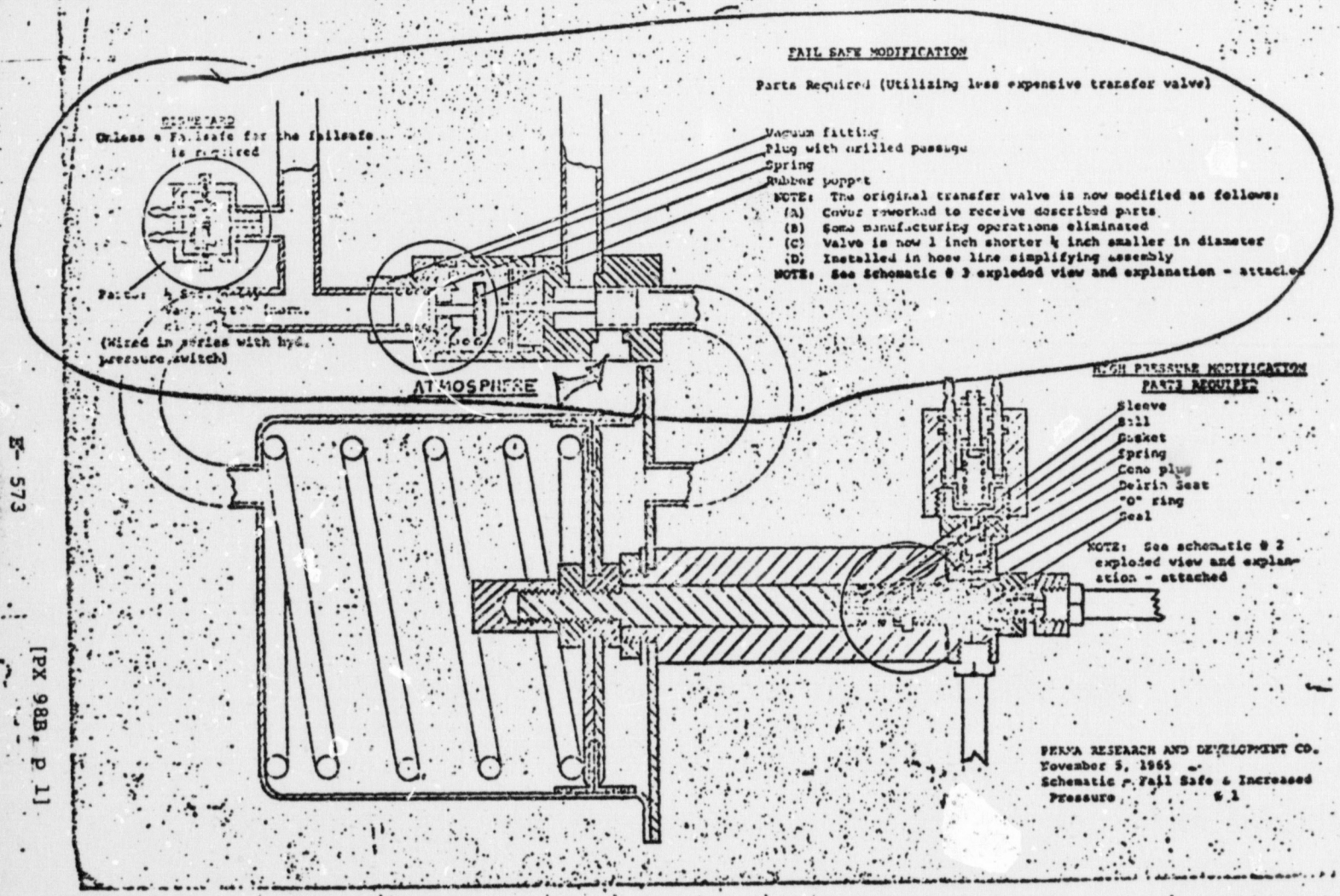
[PX 94, P 51]

[PX 94, P 51]

E-572

PLAINTIFF'S EXHIBIT 98B

SCHEMATIC SHOWING MODIFICATIONS FOR "FAIL SAFE" AND HIGHER BRAKE PRESSURES



E- 573

[PX 98B, P 1]

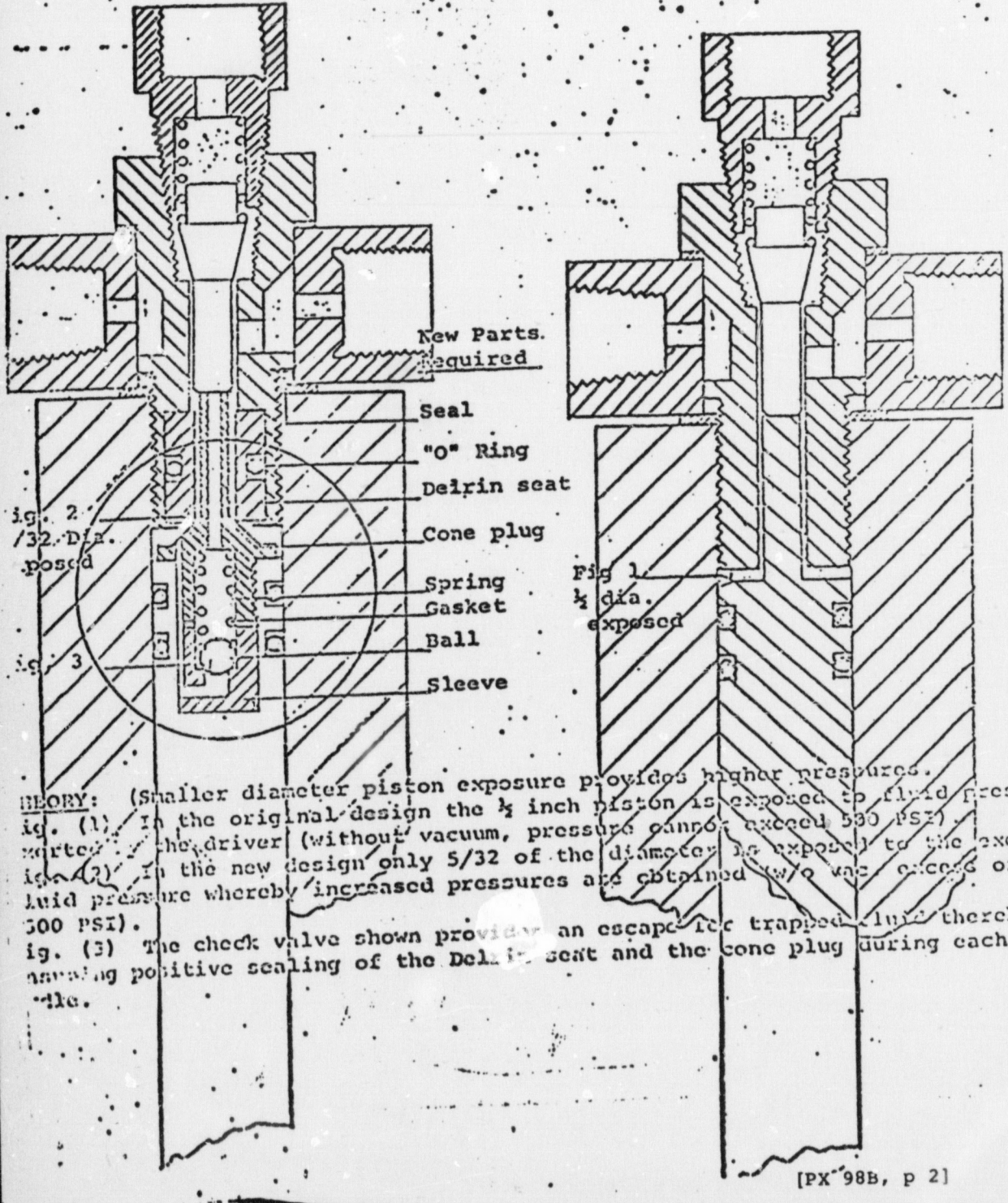
[PX 98 B, P 1]

MODIFICATION FOR HIGHER PRESSURES

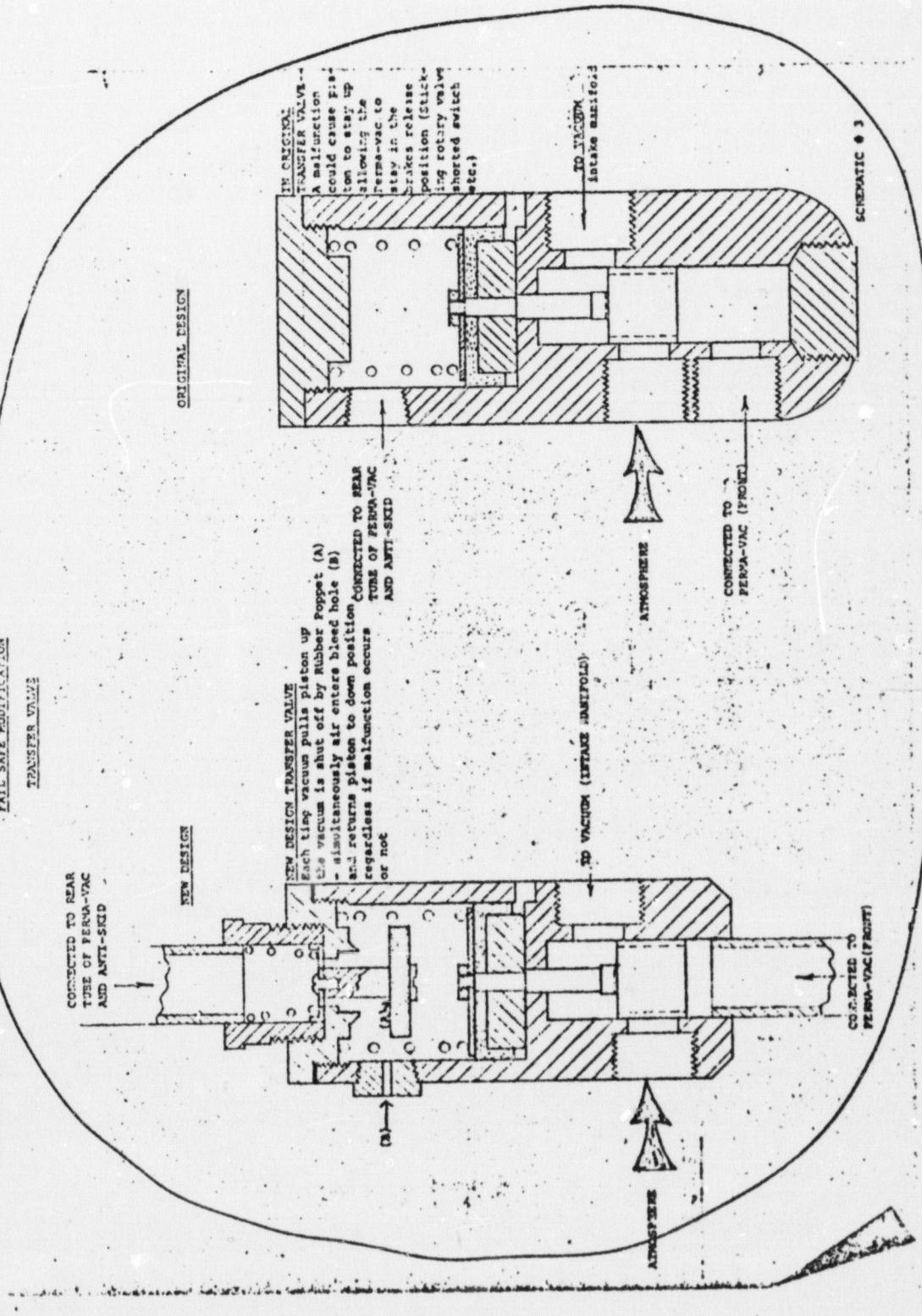
Schematic #2

NEW DESIGN
W/O Vac. 2500 PSI
W/ Vac. 6000 PSI

ORIGINAL DESIGN
W/O Vac. 500 PSI
W/ Vac. 1200 PSI



THEORY: (Smaller diameter piston exposure provides higher pressures.
ig. (1) In the original design the ½ inch piston is exposed to fluid press
arter ... the driver (without vacuum, pressure cannot exceed 500 PSI).
ig. (2) In the new design only 5/32 of the diameter is exposed to the exce
luid pressure whereby increased pressures are obtained (W/O vac. excess of
500 PSI).
ig. (3) The check valve shown provides an escape for trapped fluid thereby
ensuring positive sealing of the Delrin seat and the cone plug during each
ake.


FAIL SAFE MODIFICATION
TRANSFER VALVE
ORIGINAL DESIGN
IN ORIGINAL TRANSFER VALVE -- A malfunction could cause piston to stay up allowing the Perma-vac to stay in the brakes release position (Sticking rotary valve shorted switch etc.)
TO VACUUM intake manifold
SCHEMATIC # 3
CONNECTED TO REAR TUBE OF PERMA-VAC AND ANTI-SKID
ATMOSPHERE
CONNECTED TO PERMA-VAC (FRONT)
NEW DESIGN
NEW DESIGN TRANSFER VALVE
Each time vacuum pulls piston up the vacuum is shut off by Rubber Poppet (A) - simultaneously air enters bleed hole (B) and returns piston to down position regardless if malfunction occurs or not
CONNECTED TO REAR TUBE OF PERMA-VAC AND ANTI-SKID
TO VACUUM (INTAKE MANIFOLD)
(A)
(B)
ATMOSPHERE
CONNECTED TO PERMA-VAC (FRONT)

SINGER

30 ROCKEFELLER PLAZA • NEW YORK 20, N.Y.

MEMORANDUM

Mr. A. di Scipio

B. C. Person

November 9, 1965

REFER TO:

RECOMMENDED COURSE OF ACTION FOR PERMA ANTI-SKID CONTROL PROGRAM

The attached memorandum presents the second report of the Perma Anti-Skid Control Task Force. In this report we recommend that the Consumer Products Division enter a program of divestiture for this product.

To implement this recommendation we propose to take the following steps:

1. Arrange for Kelsey-Hayes to test units of our present design. Kelsey has been interested in testing the Perma unit since engineering discussions last March. We would expect to gain from these tests (a) an appraisal of the unit by automotive engineers, (b) an expression of the extent of Kelsey-Hayes' interest, and (c) some additional test data. Appropriate steps will be taken to ensure test results are kept confidential.

2. Work with the Corporate Development Office in the development of a strategy for approaching potential buyers. This strategy will include:

   a. a list of companies to be approached (a tentative list is attached to the report);

   b. the desired price and terms; and

   c. the minimum price that will be acceptable.

3. Continue to meet and negotiate with Perma to gain their understanding and to improve the terms of our present agreement. The royalties due Perma under the present agreement and the reversion clause both reduce the attractiveness of any package we might offer to a prospective buyer.

4. Meet with Mr. Walter P. Byers to determine what specific assistance he might provide.

Finally, we believe that a reserve of $1.5 million should be planned for in CPD's 1966 budget to cover the possibility that the present inventory is not marketable and we are unable to find a buyer.

Unless you take exception, we will proceed with these implementation steps, keeping you informed of our progress.

Original Signed by
B. C. Person

DCP:lk
Atta.

PROSPECTIVE PURCHASERS

American Motors

Kelsey-Hayes

Gulf and Western Industries, Inc.

Maremont Corp.

Midas International Corp.

Rayco Manufacturing Co. (A subsidiary of B. F. Goodrich Company)

Detroit Gasket and Manufacturing Co. (A subsidiary of Indian Head Mills, Inc.)

Divco-Wayne Corp.

Standard Products Co.

Bendix - Westinghouse Automatic Air Brake Co.

Curtis-Wright Corp.

Mack Trucks, Inc.

Firestone Tire and Rubber Co.

General Tire and Rubber Co.

Associated Spring Corp. (A subsidiary of Bowman Products Co.)

American Brake Shoe Company

Borg-Warner Corp.

DRAFT

CONFIDENTIAL

TO: Mr. A. di Scipio

FROM: Perma Anti-Skid Control Task Force

SUBJECT: PERMA ANTI-SKID CONTROL - RECOMMENDED COURSE OF ACTION

This memorandum presents the second report of the Perma Anti-Skid Control Task Force. In our first report we recommended to CPD management that the marketing effort be temporarily suspended and the units in the field be withdrawn because of the heavy legal exposure faced by Singer. The withdrawal program has moved along rapidly and this exposure has been reduced substantially.

In this report we recommend to CPD management that Singer enter a program for divesting itself of this product, recovering as much as possible of our investment. The following portions of the memorandum present:

1. a brief review of the background of this problem
2. the reasons for the Task Force's recommendation
3. a plan for implementing the recommendation

BACKGROUND

The first sketchy reports received after CPD became responsible for the Perma Anti-Skid Control program indicated that this program, in which Singer has invested nearly $2 million, might be in serious trouble. First, reports of technical shortcomings in units already on cars suggested that Singer might be faced with serious legal exposure. Second, failure of a redesigned unit to perform properly during a demonstration for CPD management cast doubt on plans, which were already under way, to make commitments for an enlarged marketing program. (This degree of unreliability is critical in a product which is sold as a safety device and affects the life or death of the occupants of a car.)

In view of the above, you appointed a Task Force to make A omprehensive study of this program in order to (1) determine whether any immediate action was required regarding units in the field, and (2) develop a recommended course of action for CPD management. The study was to cover the technical validity of the product, the implications of using Singer's name, the legal aspects--product liability and our contracts with Perma and with our distributors, the financial status of the program. and the possibilities for divestiture.

The initial findings of the Task Force confirmed the fact that there were technical deficiencies in the product and that Singer's exposure was heavy. Thus the withdrawal program, estimated to cost about $250,000, was recommended and undertaken. Field reports received during withdrawal confirmed the need for such a program. The more costly action of withdrawal of units rather than replacement with redesigned units was recommended because the date when a proven, redesigned unit would be available was indefinite.

The issue now facing CPD management--deciding on a future course of action for this program--is a difficult one because of the $2 million already put into it. Almost half of this amount, or $1 million, is in inventory tied to the present design. Four alternative courses of action are open to CPD management:

1. Make further investments in the product to bring it to a point, technically, where Singer can make and market it.
2. Try to divest ourselves of the program, recouping as much as possible of our investment.
3. Turn to Perma for recovery of our damages in the program.
4. ~~Terminate the program and write it off.~~

REASONS FOR RECOMMENDATION

From our analysis and evaluation, the Task Force recommends that CPD begin immediately to look for a means of divestiture for this program because: (1) if Singer is to continue the program, the probability that major additional investments will need to be made is high and the chance of recovering the total investment in the marketplace is low; ~~(2) the product is in a business which is not~~ basically attractive for Singer; and (3) our recourse to recovery of investment from Perma is very limited.

High Investment - Low Chance of Recovery

The Perma Anti-Skid Control unit is not ready for the market. This conclusion is reached in technical evaluations from both the Elizabeth Engineering staff and from the Research and Development Division. From a technical and marketability standpoint there are three major areas of deficiencies:

1. The present design is not fail-safe; that is, should the unit fail, it could lead to a significant reduction in or complete loss of the normal braking capabilities of the car. This deficiency is of critical importance because: (a) Singer's counsel advises that by not being fail-safe the product greatly increases Singer's legal exposure; (b) Singer's Insurance Department advises that Singer could not obtain product liability insurance if we knowingly sell a product which, due to inherent defects, could cause an accident; (c) specifications established by some of the automotive companies require that an anti-skid unit be fail-safe; and (d) the damage to Singer's quality reputation on its other products could be severe in the event of publicity stemming from a lawsuit where this design deficiency was brought out.

2. The present design has several operational deficiencies. The ones of most concern are: (a) under-low vacuum pressures from the intake line pressures do not reach design specifications; (b) the mechanics of the

(last paragraph transcribed on page E-581A)

After viewing all available copies of the preceding page, counsel for Appellant believes that the last paragraph thereof reads as follows:

> "2. The present design has several operational deficiencies. The ones of most concern are: (a) [under low vacuum pressure from the motor (?) brake line pressures]* do not reach design specifications; (b) the mechanics of the ...."

---

* This material was struck and the following handwritten material placed above it: "when the engine stalls during a panic stop, there is a loss of (?)"

...system are such that at slow speeds there is a slight lag; and (c) it is possible to "fool the unit" - that is, the brakes can be applied gently on icy roads and result in a skid without activating the unit.

3. Reliability testing of the components and of the total unit is far from complete. Some bench endurance tests have been performed, but compared to the level of testing that should go into a unit that affects the basic safety of a car, there are major shortcomings. The unit has not been field tested (1) on ice and snow, (2) at speeds below 30 mph, (3) under varying environments, such as extremes of low temperatures and high temperatures, dust and freezing rain, (4) at high altitude, (5) on long steep grades, (6) under varying car loads, (7) on cars where motor maintenance is poor, and (8) over extended mileages.

Elizabeth engineers estimate a program to resolve the operational deficiencies (not the fail-safe problem) and to provide adequate testing may require up to one year and $355,000. This design period could easily be extended in time and the cost increased to $750,000-$1,000,000 owing to the nature of development work and to the continually changing design criteria. Disc brakes are now appearing on a number of new cars; the Perma unit is not now designed for disc brakes. Front-wheel drives have appeared on the scene; the unit is not designed to operate with front-wheel drives. Also, the unit is not designed to operate on cars with gear shifts or on cars with front-wheel takeoffs for the speedometer.

While the added investment is high, the probability of recovering the investment is low. A pro forma income statement has not been prepared because of the design and thus the manufacturing costs are still changing. However, these factors are working against Singer: (1) the additional design and engineering time plus the added investment can add two years to the breakeven point given on this project at the outset of the program, moving it from the end of 1967 to the end of 1969; (2) under

the impetus of government interest and threatened legislation, the auto companies are bound to be working on similar or competitive approaches; and (3) our Patent counsel advises that the Perma patent is not broad enough to preclude "designing around it".

Auto Parts Business Not Desirable

In addition to the risk of recovering our investment, one product does not make a product line and the automotive parts business is not an attractive business for Singer.

Heavy investments in engineering staffs and automotive testing facilities would be required to compete in the industry. Even with this investment, it is doubtful whether a controlling position could be attained because of the purchasing power and engineering skills of the Big Three.

Recourse to Perma Limited

While there is a reasonable chance that Singer might legally have recourse to Perma in order to recover the damages from this venture, the latest Dun & Bradstreet Report shows a negative net worth and essentially no assets.

Action Plan

To implement our recommendation, the following action steps are proposed:

1. Arrange with Kelsey-Hayes to test our unit. This manufacturer of braking systems has evidenced interest in such tests since initial engineering discussions last March. Singer would expect to gain from these tests: (a) technical discussions and appraisal from automotive engineers; (b) an indication of the extent of Kelsey-Hayes' interest; and (c) additional performance data on the present design. Prior to any testing we would arrange for a written agreement on their disclosure of results to us and on their holding all information for internal use only.

ARMA ANTI-SKID CONTROL - RECOMMENDED COURSE OF ACTION

2. Work with the Corporate Development Office to develop a specific strategy for divestiture. This strategy would include a list of prospective buyers in order of priority, what we would like to get in a sale, and alternative terms of payment.

3. Meet with Mr. Walter Evers to determine what assistance he might provide.

4. Continue to meet with Perma executives in an effort to improve the terms of the contract. The reversion clause and royalty payments in our agreement with Perma detract from any package we might offer.

The reversion clause requires that beginning in 1966 Singer incur expenses of $100,000 per year in promoting the device; if not, Perma can reacquire the patent rights by paying certain specified sums of money. The royalty schedule briefly is:

a. Sales other than b & c below
1. None on the first 16,000 units
2. $10 per unit on the next 20,970 units
3. 10% of factory price for 5 years (above 36,970 units) 4. 5% for the succeeding 5 years

b. Sales to OEM
5% of ~~any dollar sales~~ for 10 years

c. Sales to manufacturing licensees of Singer for resale Royalty free
Royalties received by Singer on sales to OEM in which case 25% of Royalties received by Singer

We would like to eliminate the reversion clause and replace the royalty schedule with a revised schedule that would recover Singer's investment first and then share any proceeds with Perma.

PLAINTIFF'S EXHIBIT 100

S 900 (3-65)

SINGER

30 ROCKEFELLER PLAZA • NEW YORK, N.Y. 10020

MEMORANDUM

TO: Mr. B. C. Person

FROM: Alfred di Scipio

DATE: November 11, 1965

REFER TO: Your subject memorandum to me, dated November 9, 1965

SUBJECT: Recommended Course of Action for Perma Anti-Skid Control Program

Confirming our discussion (in the dark), I am in agreement with the four-point program outlined in the referenced memorandum. Please proceed accordingly.

With respect to a reserve for 1966, I have requested that we include a two million dollar ($2,000,000) pre-tax reserve for possible loss as a result of this program. Any such provision in CPD's budget would, of course, be subject to Company review and approval.

A. d. S.

cc: Messrs. S. Boriss
R. H. Elman
J. E. McConnaughy, Jr.
J. J. McGuire

RECEIVED
NOV 12 1965
BURTON C. PERSON

176

PLAINTIFF'S EXHIBIT 102

THE SINGER COMPANY

THIRTY ROCKEFELLER PLAZA · NEW YORK 20 NEW YORK

CONSUMER PRODUCTS DIVISION

November 22, 1965

Mr. Frank A. Perrino, President
Perma Research and Development Company
345 East Washington
North Attleboro, Massachusetts 02761

Dear Mr. Perrino:

This will acknowledge your letter of November 8 1965. We appreciate that it was prompted by your desire to improve the situation, but we find much in it with which we cannot agree and certain statements which we believe to be argumentative.

Mr. Romel has given his opinion on the engineering suggestions you make, and here too we regret that we are unable to accept your views.

We are happy to note your understanding that the views of Singer and Perma are presented without prejudice and subject to that understanding this will confirm our plans to meet and hold further discussions on November 22, 1965.

Mr. E. A. Salter, your patent attorney, has requested certain information from our Patent Department, and we will be pleased to furnish it to him upon the same understanding.

Very truly yours,

B. C. Person
Director of Technical Services

EXH. NO. 18A
MORAK REPORTING

11/4/70

215

[PX 104, p 1]

PLAINTIFF'S EXHIBIT 104

REC'D DEC 29 1965

THE SINGER COMPANY

THIRTY ROCKEFELLER PLAZA • NEW YORK 20, NEW YORK

December 23, 1965

Mr. R. D. Mainelli
V. P. - Production & Engineering
Perma Research and Development Company
345 E. Washington
North Attleboro, Massachusetts 02761

Dear Mr. Mainelli:

This letter is written in reply to your letter of December 2, 1965. In view of the numerous telephone conversations between Mr. Perrino and myself and between Mr. Perrino and the engineering personnel at our Elizabeth Plant, I do not understand why you say "nor do we know what your engineers' objections are to our suggestions."

However, as a matter of clarification, we cannot agree with many of the statements made in Mr. Perrino's November 8, 1965 letter about the events that transpired between Perma and Singer at the meeting of October 15, 1965. Also, we believe many of the statements to be argumentative. We do not plan to debate them via the mail.

As regards the engineering suggestions Mr. Perrino made in his letter of November 8, 1965, he implies that the minor product modifications "overcome all the objections raised at the meeting regarding the product." As he is aware, one of our primary concerns is that the Perma unit, as presently designed, is not fail-safe. Perhaps some of our disagreement arises out of difference in the understanding of the meaning of "fail-safe." We do not regard a device as fail-safe unless failure of the device, regardless of cause or probable frequency of a particular type of failure, does not impair the utility of the underlying system to which it is connected. Our engineers advise that the modifications suggested in Mr. Perrino's letter of November 8, 1965 do not produce a fail-safe design. In fact, the Perma Research and Development Company's Schematic #1 suggests that the minor modifications suggested do not produce a fail-safe design; the schematic shows a one-half second delay vacuum switch as backup for the modifications.

If you are convinced that the modifications suggested result in a design which will not, under any conditions, impair the utility of the underlying system, I believe a meeting between yourself and our engineering staff is warranted and would be pleased to arrange for such a meeting.

Very truly yours,

B. C. Person
Director of Technical Services

BCP:lk

EXH: NOA
MORAK, REPORTER

11/4/70

SCHEDULE B

PERMA DEVICE

MANUFACTURING UNIT COSTS
1965 REVISED STANDARD*

	Dual	Single
Material	$ 36.83	$ 33.88
Direct Labor	.99	.57
Variable Overhead	3.25	2.01
Total Variable Cost	41.07	36.46
Period Costs	12.29	8.40
TOTAL COSTS	$ 53.36	$ 44.86

* Represents the cost of the present redesigned unit and is approximately $10.00 higher than the original standard.

THE SINGER COMPANY
400 LAST MAIN STREET • DENVILLE, NEW JERSEY 07834

CENTRAL RESEARCH LABORATORY

TELEPHONE (201) 627-4600
REFER TO:

PLAINTIFF'S EXH 110-A
DATE 3/31/71
LAWRENCE GREENBERG

November 8, 1965

CRO:gc

RECEIVED
NOV 9 1965
BURTON C. PERSON

Mr. B. C. Person
Director of Technical Services
Consumer Products Division
The Singer Company
30 Rockefeller Plaza
New York 20, N. Y.

Dear Mr. Person:

Evaluation of Perma Anti-Skid Device

In accordance with a recent telephone conversation had with you, enclosed are two copies of Denville Special Report #62 titled "A Technical Evaluation of the Perma Anti-Skid Control Based on Present Design". This report is a revision of the draft forwarded to you with Mr. Momberg's letter of July 28 and, in this connection, we would ask that the draft presently in your possession be returned to us.

The above report is an engineering analysis of the Perma Anti-Skid device based on information available to us and some experience had by Mr. Lundin during his work with Elizabeth factory. This report also includes a rough estimate and description of development work we feel should be undertaken if it is decided to continue in this business.

We believe this report answers most of the questions that you have asked in previous correspondence and discussions that it is possible for us to answer with the information currently available to us.

It is the writer's opinion, though not positively stated in the report, that The Singer Company should not market a device of this type that is not fail-safe (fail-safe is used here and in the report as applicable to the anti-skid device only). In other words, any device of this type should not degrade the fail-safe characteristics of the braking system to which it is applied. This opinion is based on my own feelings that a device of this type which is not fail-safe would not be consistent with the high quality standards Singer applies to the other products that it manufactures and markets.

T 2 71

B. C. Person

One question not completely answered is that of what percentage of the inventory could be salvaged if a redesign of the type proposed were undertaken. Without having completed the development phase proposed, it is difficult to be very specific concerning this area. However, since the components which are to be redesigned represent a significant part of the total system, it is reasonable to assume that a large percentage of the total inventory would not be salvaged - as a wild guess, 50% or better.

The patent situation on the present device appears to be somewhat confusing and, from our discussions with the patent people familiar with the device, we could not get a clean statement of exactly what patent claims will be secured for the device. On this basis, we cannot predict whether a redesign will stay within the patent claims and could only submit such a redesign to the Patent Department for a statement by them as to whether what is being proposed is or is not within the claims of the Perma Anti-Skid device.

Since we believe that the deficiencies in this device go much beyond whether the reliability of the device has been proven or not, we have not attempted to define or estimate the cost of a test program to establish reliability. In fact, we do not feel that we have sufficient background in automotive devices to specify a realistic test program to establish reliability. This type of program should be established by people with adequate engineering background in automotive devices.

Very truly yours,

C. R. Odermann
Laboratory Director

Encl. (Two copies of Denville
Special Report #62)

cc: Mr. J. W. Momberg
Mrs. O. Goebel, Librarian

Controlled Technical Information

THE SINGER COMPANY
CENTRAL RESEARCH LABORATORY
DENVILLE, NEW JERSEY

Denville Special Report #62

A TECHNICAL EVALUATION OF THE PERMA ANTI-SKID CONTROL BASED ON PRESENT DESIGN

Project #01-0211

Written by:
MR. J. A. LUNDIN
November 5, 1965

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INTRODUCTION

Upon acquisition by The Singer Company of the rights to manufacture and market the Perma Anti-Skid Brake Control device, an evaluation of the device was undertaken by Singer-Elizabeth personnel. In actual road tests deficiencies in performance and reliability were uncovered.

It became readily apparent that this device could not be placed on the market until performance and reliability were improved to a point where they were beyond question.

A modest engineering effort was undertaken by Singer-Elizabeth to make (quick fix) improvements in the device. Singer-Denville was invited to participate initially to test components and finally on a consulting basis.

On the following pages an attempt is made to evaluate the Perma device as it stands today. It is hoped that by putting things into a proper perspective a course of action will be indicated.

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DEFICIENCIES IN PRESENT DESIGN

The present anti-skid design is not fail-safe. As now constituted, full braking pressure during normal operation is obtained only by applying a vacuum to the piston side of the diaphragm in the Perma-Vac unit. This vacuum creates a differential pressure across the diaphragm which acts in a direction to assist a spring in maintaining a force against the piston. This force, differential pressure plus spring pressure, acting against the piston is large enough to permit build up of full braking fluid pressure thereby permitting normal braking during normal driving.

In the event of loss of vacuum only the spring force acts against the piston. It is estimated that with a vacuum failure normal braking pressure is reduced from approximately 800 p.s.i. to 400 p.s.i.--roughly 50%.

It should be noted that the above reasoning also holds true in the event of a panic stop. A loss of vacuum would result in maximum cycling brake pressure being reduced as previously noted.

Loss of vacuum can result from stalling of the engine, which occurs quite often during panic stops, and also through air leakage into the vacuum side of the system. Loss of vacuum through air leakage is particularly insidious since it can occur without warning to the operator.

The present anti-skid design is such that, during operation, cycling takes place over a wide pressure range. System performance (stopping distance) would be considerably enhanced if the low end

of the pressure range were increased so that cycling occurred between just above locked-wheel pressure and just below locked-wheel pressure.

At present, pressure at the low end of the range is low enough to cause opening of the pressure switch contacts. This has the effect of over-riding or inactivating the governor until pressure builds up to wheel-lock pressure at which time the governor regains control. As a result, the system operates at low brake pressure for an unduly excessive time. THE ACTION OF THE GOVERNOR IS THE SOLE MEANS OF DETECTING USABLE ROAD FRICTION.

Another undesirable feature of the present design is that the anti-skid activating mechanism can be fooled. Tests with the present design indicate that gradual application of brake pressure can result in a skid condition (locked wheels) without activating the anti-skid brake control. Not all skidding occurs as a result of panic stops. Skidding can occur, for instance, during gradual braking on slippery roads.

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OTHER NEGATIVE ASPECTS OF PRESENT DESIGN

Reliability of all system components and assemblies has not been established. There are a number of inherent features in the design which raise the question of reliability with regard to the performance of certain functions. The questionable components and assemblies include the solenoid return spring, the rotary valve and valve leverage, the governor expansion spring and associated parts and the sensor cam gear.

The present design is not applicable to cars which have manual shift transmissions, disk brakes, front wheel drives, front wheel speedometer take-offs, and other than 12-volt electrical systems.

Furthermore, the present design has demonstrated encouraging results only on cars with dual brake systems. Performance has been unsatisfactory on cars with single brake systems. It should be noted that at present single brake systems are in use on almost all cars. Notable exceptions are the Cadillac and American Motors automobiles.

Another consideration of some importance is the fact that the automotive industry is in a constant state of flux. Changes in vehicle design for economic and competitive reasons occur with great rapidity. The implications of how these automotive design changes will relate to the anti-skid device can be far reaching. The most that can be stated here based on present day trends is that functional design of an anti-skid control system should not be critically dependent on vacuum levels and should be compatible with higher brake fluid pressures.

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Finally, it would seem wise to carry out a broad test program on the anti-skid device. This has not been done to date. A minimum of life test data is available. No data is available for system performance at low temperatures, high humidity, high altitude, icy and slushy roads, hilly roads and at speeds below 30 miles per hour.

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REDESIGN CONSIDERATIONS

In order to correct the deficiencies existing in the present anti-skid device, the following corrective design work is indicated:

(1) The Perma-Vac piston and spring should be redesigned so that piston response during cycling is rapid and positive even though vacuum pressure is a minimum.

It is believed that a new piston design may be possible which would permit restraint of the brake fluid pressure in the event of a vacuum failure.

The anti-skid device would benefit from the above changes in that the increase in frequency response would permit pressure cycling near locked-wheel pressures. Also, the anti-skid device would be fail-safe with regard to vacuum failure. These changes should also result in the lowering of the critical vacuum level as well as permitting the use of higher brake fluid pressures should this become necessary or desirable.

(2) The manner in which the governor and rotary control valve function is another area where corrective redesign is necessary. It is presently assumed (pending a system function analysis) that the following governor characteristics are desirable:

(a) It should be sensitive and highly responsive to changes in wheel speed throughout the entire speed range.

(b) It should generate sufficient force even at low speeds to reliably drive the valve.

(c) A direct proportionality should exist between governor action and wheel speed. (A function analysis may cause a revision in thinking here.)

To approach the above governor characteristics, it is proposed to separate the system inertial energizing source from the governor function and redesign the governor. This redesigned governor would correctly follow wheel speed and generate sufficient force to drive the valve reliably.

In addition, the present valve design does not suggest proportional control characteristics. A new sensor valve should be designed taking into account the functional characteristics of the non-uniform vacuum source as well as the vacuum requirements of the Perma-Vac unit.

These changes should result in an improved frequency response, optimum functional vacuum control, and a more reliable valve control all of which would facilitate cycling near locked-wheel pressures.

(3) In (2) above reference was made to the separation of the system inertial energizing source from the governor function. In order to provide sensitive, fool-proof skid detection, the storage of inertial energy, a function presently performed by the governor, would be provided by another (new) component.

This change should not only result in a fool-proof anti-skid system but would also remove the need for retraining the experienced driver to slam down on the brake pedal.

The corrective design discussed above appears deceptively simple. The reader should not be deluded into thinking that a successful redesign is a foregone conclusion. It should be emphasized that the remedial action suggested exists only in the idea stage backed by engineering judgment.

Redesign is further complicated by patent considerations. It has been requested that every effort be made to carry out the redesign work within the protection afforded by patents acquired by The Singer Company. However, because the proposed redesign does not exist in concrete, detailed form, and because a measure of inventiveness and ingenuity will be required on the part of the designer, no guarantee can be given at this time that the required functions can be achieved within the protection afforded by the patents.

For similar reasons no determination is possible at this time as to how much of present inventory can be saved.

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A PROPOSAL FOR REDESIGN

The necessary engineering and development work would be carried out in three phases as follows:

Phase I — A complete system function analysis to gain a more thorough understanding of the various functions and how the functions of the various components are interrelated.

Phase II — The design and development of necessary system components to achieve the required functions (within patent protection if possible) and acceptable reliability and performance.

Phase III — Installation of the complete system in a vehicle and road testing. Road testing to be performed by Singer-Elizabeth. Singer-Denville will retain responsibility for any design changes within the scope of this proposal shown by road tests to be necessary.

It is estimated that the above work will cost $30,000.00 and req[illegible] nine months time to complete.

The above cost estimate does not include the cost of any Singer-Elizabeth personnel who may become involved in this work. (As in Phase III, for instance).

It presumes cooperation from Singer-Elizabeth personnel and possible use of their test equipment such as the CEC recorder, transducers, and test stands as the need arises.

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CONCLUSIONS

The anti-skid device in its present design is not ready for a marketing effort for the following reasons:

(1) The unit is not fail-safe.

(2) The activating mechanism can be fooled by gradual application of brake pressure.

(3) Performance with regard to stopping distance is questionable.

(4) Reliability of a number of system components is questionable.

(5) The device has not been thoroughly road tested. No data is available for system performance at low temperatures, high humidity, high altitude, icy and slushy roads, hilly roads and at speeds below 30 miles per hour.

Furthermore, the market which is available to the existing anti-skid device is severely restricted because it cannot be used on cars with single brake systems. The overwhelming majority of cars are presently built with single brake systems.

On the foregoing pages an approach to the solution of the major problems is broadly outlined. However, at this time, it cannot be stated categorically that the suggested solutions will yield the desired end product.

As previously stated, redesign is further restricted by patent considerations. Because of the inventive nature of the redesign work, no guarantee can be given at this time that the required functions can be achieved within the patent protection afforded by patents acquired by The Singer Company.

For the same reason no determination is possible at this time as to how much of present inventory will be usable in a redesigned anti-skid device.

PLAINTIFF'S EXHIBIT 120

SINGER

MEMORANDUM

RECEIVED
DEC 21 1964
D.D. MARSDEN

TO: Mr. D. D. Marsden

cc: Mr. C. T. Meany
Mr. P. Phelps
Mr. R. A. Kloby

FROM: R. S. Torello

DATE: December 21, 1964

REPLY TO

SUBJECT: Acquisition of Perma Research & Development

The Manufacturing Division proposes to enter into an agreement with Perma Research and Development Corporation for the acquisition of all its patents, trademarks and marketing rights on their anti-lock and anti-skid breaking device. Singer would assume $210,000 of Perma's liabilities, pay $24,000 cash to Perma for Canadian inventory and purchase Perma's present U. S. inventory for $112,563, making a total commitment of $346,563. On June 18, 1964, Elizabeth entered into an agreement with the Perma Corporation to assume purchase order commitments from approximately 25 subcontractors for the manufacture of Perma anti-skid component parts. The purchase commitments are detailed as follows:

Supplier	Purchase Commitment
American Emblem	$ 103,485
American Optical	$ 800,161
Other Suppliers	$ 517,673
	$1,421,319

In addition, it will be necessary to purchase $146,000 of additional components to take care of projected 1965 needs. If repair and rework of existing inventory, technical service costs, marketing costs and start up costs all totaling $326,000 are viewed as additional initial commitments, then Singer's investment at risk is detailed below:

Purchase Commitments	$1,421,319
Acquisition of Perma	234,000
Acquisition of Perma Inventory	112,563
Additional Components Required	146,000
Start Up Costs	50,000
Repair, Rework or Existing Inventory	131,000
Marketing Costs	20,000
Technical Services	125,000
	$2,239,882

However, if Singer does not acquire Perma, they estimate their commitment of Perma inventory at approximately $1,000,000 composed of $600,370 of inventory present at Elizabeth on October 31, 1964 and approximately $400,000 of purchase order commitments that would have to be honored by Singer. Thus, if Singer were to acquire Perma rights and assets, the

FTC 377

incremental investment is actually $1,239,882 relative to not acquiring the company. If this acquisition is not consumated, Elizabeth believes that Perma Research & Development Corporation could go bankrupt and the Perma inventory held by Elizabeth would have to be liquidated or written off. The Elizabeth people believe that the Perma inventory could not be liquidated for an amount near the purchase price and a large inventory write-off would be incurred.

Perma Research & Development markets a device that prevents locked brakes under heavy braking pressure and eliminates the possibility of skidding. Total braking distance is less using the Perma device as shown by the following table:

BRAKING EFFECTIVENESS
OF PERMA DEVICE (1)

Speed in Miles Per Hour At Initial Braking	Braking Distance	
	Normal System	Perma System
20	21.4 ft.	19.2 ft.
30	50.0	46.0
40	83.0	77.0
50	122.5	112.0
60	171.9	156.3

(1) Test conducted on dry pavement by the Motor Vehicle Research Bureau.

The listed retail price of this device to the end consumer will be $120.00 per unit plus an estimated installation charge of $10.00. Substantial discounts from list price can be offered to quantity users. Elizabeth estimates that Perma has sold only 1,000 units to date because of quality problems that existed on component parts manufactured by Perma's subcontractors.

Elizabeth proposes to market the anti-skid device through Monitor Enterprises, one of Perma's regional distributors. Perma would not continue to market the device since Elizabeth believes that the firm would not be as effective as Monitor. Monitor has guaranteed to take 50,000 units during the first twelve month period and has agreed to spend $250,000 for advertising and promotion during this period. A net worth statement of Monitor is currently not available but Elizabeth believes that Monitor presently does not have the financial resources to back this guaranteed advertising expenditure. Monitor Enterprises is a small firm with five salesmen that currently sells a product that measures air pressure in the tires from a guage inside a truck or auto. Most of the salesmen's time is spent calling on truck fleet owners rather than auto dealers, government agencies or retail outlets which may constitute a significant portion of Perma's projected customers. Elizabeth would like marketing arrangements to remain flexible as the effectiveness of Monitor and their sub-distributors is evaluated.

Exhibit 1 shows the projected operating results from the anti-skid device U. S. manufacturing operations. Elizabeth also projects (not shown on Exhibit 1) the sale of parts for 12,000 units to St. Johns to be sold in the Canadian market at a transfer price of $34.50 per unit. No details concerning marketing arrangements in Canada are available. The following table is a summary of Exhibit 1:

	Number of Units Sold	Sales Volume (000's)	Net Income After Tax (000's)	Net Income as % of Sales
1965	50,000	$2,550	$ 115	4.5%
1966	100,000	4,850	560	11.5
1967	200,000	9,700	1,314	13.5
1968	200,000	9,700	1,439	14.8
1969	200,000	9,700	1,439	14.8

If it is assumed that the average retail price per unit sold is $110 allowing for quantity discounts, then the retail sales volume of this one product line would be $22,000,000 by 1967. Net Income after tax at the manufacturing level is projected at 13.5% of sales in 1967. The additional investment in working capital and fixed assets required to achieve the 200,000 unit level in 1967 is not currently available. However, to produce 100,000 units on the most economic basis, Elizabeth feels that a fixed asset capital commitment of approximately $210,000 would be required. Further details on projected additional investment have been requested from Elizabeth.

On the basis of the preceding facts and the projected operating statements, the following points should be emphasized.

- No detail of sales by customer or by meaningful classification is available. This detail is important due to the large projected sales increase. A market survey has been completed by William E. Hill, a consulting firm, but it currently is not available. Elizabeth believes that the potential market for this device can generally be described as follows:

    a) Individual car owners.
    b) Fleet owners (Avis, Hertz, Telephone Companies, etc.).
    c) Government Agencies (Post Office, Armed Forces, Police Departments, etc.).
    d) Automobile manufacturers.

- Perma has sold only 1,000 units to date. The achievement of sales projections may be a high risk situation in light of the projected retail price, the uncertainty of the marketing arrangements, the quality problems existing on the units sold to date and the limited results achieved to date.

Mr. D. D. Marsden December 21, 1964

- The projected transfer price from Singer to Monitor is projected at $51.00 per unit during 1965 and $48.50 thereafter. Due to the lack of sales experience at the projected $126.00 retail level, the possibility of a significant retail price reduction which may affect Singer's price to Monitor would appear to be high.

- Estimated unit manufacturing cost is projected at $30.35 in 1965, $27.30 in 1966 and $26.00 in 1967. Original projections made in May 1964 supplied by Elizabeth estimated unit costs at $18.80. Elizabeth feels that the projected cost figures from 1966 to 1969 are very conservative. Further details on projected unit costs have been requested from Elizabeth.

- The approximate break-even point for Singer to recover their total $2,239,882 initial investment is approximately 52,000 units at the $51.00 price. The number of units necessary to be sold to recover the incremental investment of $1,239,882 plus additional fixed costs is approximately 28,360 units. It should be stressed that these break-even points are greatly dependant on the projected $51.00 transfer price to Monitor. Should Monitor encounter difficulty in selling these units and Elizabeth be forced to lower transfer price then the break-even point can increase significantly depending on the size of the reduction.

- It is suggested that if an agreement with Perma is concluded, it should include marketing rights and patents for countries outside the U.S. and Canada.

Due to the commitment Singer has made to date, it may appear desirable for Singer to acquire this company. However, unless the acquisition of Perma and its inventory is an attractive long term diversification for Singer, it should not be acquired because of previous commitments. In addition, if there is uncertainty in achieving the 28,360 unit break-even point, or in maintaining a $51.00 transfer price, then it would be more desirable to liquidate, write off or find another buyer for the current Perma inventory held by Singer.

R. S. Torello

R. S. Torello

Exhibit 1

PERMA ANTI-SKID
PRO-FORMA INCOME STATEMENT
(000's)

	1965	1966	1967	1968	1969
Sales	$2,550	$4,850	$9,700	$9,700	$9,700
Federal Excise Tax @ 8%	189	359	719	719	719
Net Sales	2,361	4,491	8,981	8,981	8,981
Cost of Sales	1,517	2,730	5,200	4,940	4,940
Standard Gross Margin	844	1,761	3,781	4,041	4,041
Additional Costs					
Royalties	296	449	898	898	898
Repair & Rework - Gear Box	87				
Additional Ops.-Sensing Unit	44				
Marketing Costs	20	20	20	20	20
Technical Services	125	125	125	125	125
Start Up Costs	50				
Total Additional Costs	622	594	1,043	1,043	1,043
Net Income Before Tax	222	1,167	2,738	2,998	2,998
Income Tax	107	560	1,314	1,439	1,439
Net Income After Tax	$ 115	$ 607	$1,424	$1,559	$1,559
Number of Units Sold	50,000	100,000	200,000	200,000	200,000
Price Per Unit	$51.00	$48.50	$48.50	$48.60	$48.50
Average Cost Per Unit	$30.35	$27.30	$26.00	$24.70	$24.70

Exhibit 2

PENNA RESEARCH AND DEVELOPMENT COMPANY

Statement of Income

for the year ended June 30, 1964

Sales and miscellaneous income		$ 80,404
Cost of sales:		
Inventory at beginning	$ 60,514	
Purchases, less costs charged to development expense, $59,764	213,984	
	$274,498	
Less - Inventory at end	201,913	72,585
Gross profit		$ 7,819
Development, promotional and selling and other expenses:		
Product development	$ 67,717	
Advertising and sales promotion	56,287	
Travel and auto expense	11,673	
Telephone	8,049	
Sales salaries	35,637	
Officers salaries	25,049	
Other salaries	38,558	
Payroll taxes	5,009	
Blue Cross	1,228	
Insurance	5,510	
Legal and accounting	18,339	
Office and advertising supplies	7,742	
Office expense and postage	3,331	
Equipment rental	2,146	
Rent, freight and storage	4,626	
Shipping supplies	2,725	
Shop expense and maintenance	2,762	
Heat, light and power	1,496	
Local taxes	2,145	
Bad debts	2,752	
Miscellaneous	883	
Interest paid	5,254	
Discounts earned, less discounts allowed	(3,869)	
Depreciation of plant and equipment	15,971	
Amortization of patent	12	
Amortization of unrecovered promotional and development expense	67,369	388,421
Net loss for year		$(380,602)
Deficit at beginning of year		(212,014)
Deficit at end of year		$(592,616)

PLAINTIFF'S EXHIBIT 121

SOCIETY OF AUTOMOTIVE ENGINEERS, INC.
Un Participant ... N.Y. 10017

Evolution of Sure-Track Brake System

R. H. Madison
FORD MOTOR COMPANY

Hugh E. Riordan
KELSEY-HAYES CO.

SOCIETY OF AUTOMOTIVE ENGINEERS

International Automotive Engineering Congress
Detroit, Mich.
January 13-17, 1969

690213

Evolution of Sure-Track Brake System

by
R. H. Madison
FORD MOTOR COMPANY
and
Hugh E. Riordan
KELSEY-HAYES COMPANY

INTRODUCTION

In the more than seven decades of vehicular brake development, evolutionary improvements have been seen in, successively, the adoption of four-wheel systems, the switch from mechanical to hydraulic actuation, the addition of power assistance, the improvements in brake lining materials, and the introduction, more recently, of disc brake systems, dual master cylinders, and system failure warning lights.

A significant and dramatic advance in that evolution has been the recent introduction of an automatic anti-lock system, under the trade name Sure-Track, for mass production vehicles.

The possibility of significantly improving the performance of the vehicle-driver system by automatic assist in the braking function has been studied for many years. In particular the improvement of directional stability and reduction of stopping distance by automatically preventing locking of braked wheels was proposed at least as early as 1932. (1)*

The fact that maximum tractive force between the tire and road is obtained at values of slip greater than zero was apparently first clearly recognized around 1955. (2) (3)

The physical groundwork thus was established which showed that improvements in both stopping distance and vehicle stability should be realizable with an automatically controlled braking system.

Meanwhile, speed and weight of motor vehicles were increasing and density of traffic was growing. These trends, combined with increasing public acceptance of a higher level of sophistication in automotive auxiliary equipment, provided the motivation and the confidence in commercial feasibility which have led to the development of the first commercially feasible automatically controlled braking system for passenger cars.

ABSTRACT

The history, system philosophy, design evolution and performance of the Sure-Track anti-lock automotive braking system are presented and discussed. Considerations of performance, driver skill, reliability and commercial acceptance resulted in the choice of a vacuum-electronic rear wheel anti-lock system that incorporates individual wheel speed sensing and control of braking as a pair.

The system provides superior directional stability under "panic" braking conditions while maintaining stopping distance equal to or shorter than those for locked wheels under most road conditions.

*The numbers in parenthesis indicate references at the end of the paper.

HISTORY

Some 15 years ago, the aircraft industry succeeded in developing experimental systems to prevent wheel lock during braking. Their interest centered mainly around the problems of tire flattening and tire explosion which took place when a wheel locked at high landing speeds. Up to this time, the problem had been coped with by an overly cautious use of brakes at touchdown, resulting in longer landing runs.

Since the experimental aircraft system exhibited improved stability performance on the runway, engineers of the Ford Product Research organization became interested. They obtained an anti-lock unit from a French aircraft and installed it on a 1954 Lincoln sedan with a full power brake system. Although testing indicated improvements in stopping distance and stability, the installation created serious vibration problems in the suspension and caused the front wheels to vibrate about the king pin axis. This was typical of the many developmental problems that had to be overcome before a commercially acceptable design could be introduced.

In succeeding years, Ford research engineers experimented with internal designs, evaluated designs presented by domestic and foreign component manufacturers, and jointly set about establishing anti-lock system requirements.

Kelsey-Hayes first became interested in automatic braking systems in 1957 and started an exploratory development program at that time. Various approaches to the problem of optimum braking control were investigated. As a result of this work it was soon concluded that the single most useful contribution to brake control would be a means of preventing loss of control and reducing stopping distance under panic braking conditions.

Sure-Track anti-locking system represents the optimum workable system presently available as a result of these Ford and Kelsey-Hayes investigations. The technical team which developed it also included the Hydro-Aire Division of Crane Company, Texas Instruments, Inc., Brown Engineering Division of Teledyne, Cornell Aeronautical Laboratory, Battelle Memorial Institute, Rensselaer Polytechnic Institute, Booz Allen & Hamilton and numerous other consultants and specialized manufacturing firms.

FUNDAMENTAL TECHNICAL CONSIDERATIONS

Some improvement in vehicle stability can be achieved with very simple equipment by automatically "pumping" or pulsing the brakes in an arbitrary pre-programmed way (5). However, basic tire friction data (6) showed that, under certain conditions, controlling the brakes so that wheel slip remained in the vicinity of an optimum value could increase brake effectiveness by a theoretical factor of as much as 2.3. This made it seem worthwhile to use a feedback approach which used data sensed on the vehicle during deceleration.

The variety of physically feasible methods of producing the necessary information for closed-loop braking control and of using this information is enormous. In order to arrive at a rational basis of choice it was necessary to establish standards of performance properly related to the practical realities of economics, driver skill, system reliability, and acceptability to drivers.

Based on literature surveys, mathematical analyses, computer simulations, and vehicle tests, we arrived at the following conclusions, which served as a guide in all development work:

1. It is possible (with a relatively simple braking control system) to provide a significant improvement in vehicle stability during panic braking with road friction from 1.0 to as low as .05 and for a complete range of driving speeds.
2. In general, there need be no significant increase in stopping distance with a simple control system, except under certain specific — and uncommon — road conditions (e.g. loose gravel, loose dry snow), and there can be major reductions in stopping distances under many common driving conditions (e.g. wet pavement, ice).
3. Simple means can be incorporated in the brake control system to preclude loss of normal braking capability for any probable mode of failure of the control system.
4. It is preferable to incorporate additional functions in a control computer rather than employ complex sensing systems.
5. Until a higher level of public driving skill can be achieved than now exists, an automatic braking system should require no changes in driver habits or reflexes for maximum safety.
6. The cost to the user can be sufficiently low so than the system will come into reasonably widespread use.
7. Service and repair should require a level of skill no higher than that required for present vehicle systems.
8. Assembly on the vehicle should be compatible with present methods.

These requirements also were confirmed in a study conducted by Kelsey-Hayes in 1967 for the General Services Administration (7).

Although it is not within the purpose of this paper to present the pros and cons of two-wheel and four-wheel brake application control systems, the authors are well aware of the many comparisons of complexity, performance, cost, and state of the art that can be made.

One overriding argument for developing the two-wheel system was that its inherently simpler design promised earlier development success than did the four-wheel system.

A second, important consideration favoring the two-wheel system is based on a point also made by Harned and Johnston (5), to the effect that, with four-wheel anti-lock systems, the driver may have to apply corrective steering action in order to maintain directional stability under some conditions.

With a two-wheel system, no special new driver skills or training should be necessary. Our position is that the advantage of early introduction of two-wheel control far outweighs any slight, eventual performance edge that might be obtained with the four-wheel system. This is not to say that four-wheel control is impractical or undesirable in the long run. We simply believe that at this time, two-wheel control represents the best solution from the viewpoints of both the public and the automotive industry.

THE CONTROL PROGRAM

Although automatic skid control systems have been in widespread service in aircraft since about 1960, this technology has been of only limited value as a basis for the automotive problem because of basic dissimilarities in both the physics of the problem and the circumstances surrounding system use.

- The tire friction mechanism differs significantly because the higher aircraft speed results in high pressure steam generation at the tire-road interface on wet surfaces and melting rubber on dry surfaces.
- The required dynamic range of the aircraft system is much smaller because the pilot is required to judge the runway condition and make a manual selection of system response.
- Runway surfaces are more consistent than public roads; hence, rapid changes in friction coefficient during a stop are unlikely, and large variations in friction coefficient between right and left wheels are unusual.
- Since the maintenance of aircraft is very stringent, severe unbalance among braked wheels is unlikely. On the other hand, the dual servo brakes widely used in road vehicles will show large variations in brake coefficient from wheel to wheel if they have been abused by overheating, glazing or contamination. The need for assuring stability and good stopping distance with unbalanced brakes places another stringent requirement on the automotive skid control system.
- Finally, aircraft brake control systems cost from $500 to $1500 per controlled wheel while, to be feasible economically, the car system cost at the supplier's plant must be only a small fraction of this for the entire system.

In general, the problem of optimum automotive braking control represents an almost classic case of intractability. In mathematical terms, the car under extreme braking is represented by a tenth-order system of non-linear differential equations with time-varying coefficients. The problem is made more difficult because quantitative data on the behavior of the tire-road system are almost totally lacking, except for the measurements reported by Harned & Johnston (8) and Meyer and Kummer (6). Knowledge is sketchy at best of such factors as the difference, if any, between steady state and transient behavior, the influence of suspension dynamics, the effects of tire tread design and composition, and tire construction.

In such circumstances of insufficient data and understanding, the answer of the control engineer is to enclose the unknown elements of the system in a feedback loop. (Fig. 1). If the loop gain AB is sufficiently high over a broad band of frequencies and signal levels, the response of the system is governed only by the transfer characteristics of the feedback element.

Unfortunately, in some systems — and the car is one of these — the output response (in this case stopping distance and attitude) cannot be measured conveniently and fed back into the control system. Furthermore, in some cases — and again the car is one — the frequency and amplitude range of the available, easily sensed information occupy the same region as noise or unwanted signals. For example, there are suspension and tire resonant frequencies which cover the range from 1 to 22 cycles per second (cps), while the response of a wheel entering and recovering from a skid covers a time regime corresponding to a band width of about 10 cps.

One means of handling such a control problem lies in the use of the so-called model reference self-adaptive control technique (Fig. 2). The model is an idealized electrical analog of the system to be controlled. For example, it could represent a single wheel, unsuspended vehicle with an idealized brake

TYPICAL FEEDBACK CONTROL SYSTEM

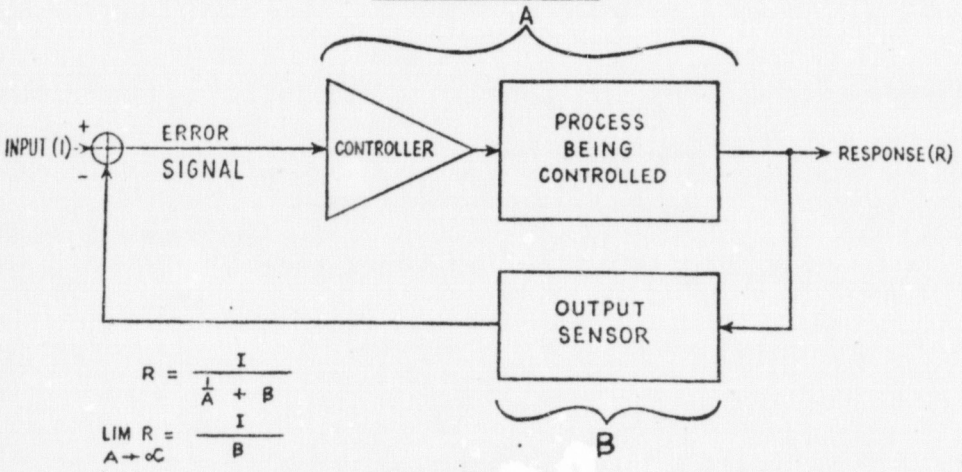

Figure 1

A MODEL-PREDICTIVE SELF-ADAPTIVE BRAKING CONTROL SYSTEM

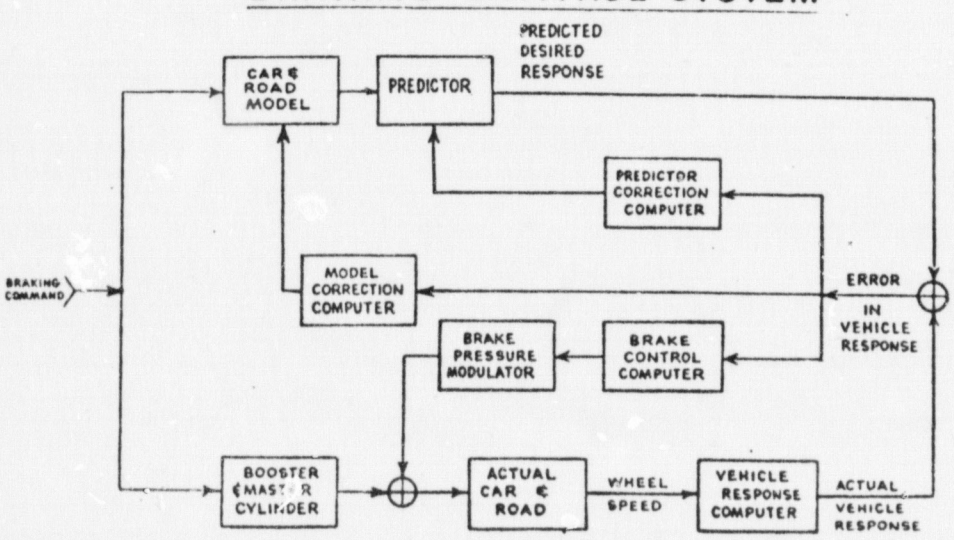

Figure 2

system (no fade, grab or hysteresis) and an ideal tire-road friction characteristics. The brake command is fed into the model, which computes an ideal wheel speed vs. time characteristic against which the actual wheel speed is compared. The error signal is used to control the brakes in such a way as to cause the real and ideal wheel speeds to coincide. Meanwhile, the magnitude of the error signal is assessed, and its character is used to modify some of the model properties to improve the accuracy of its representation, and to adjust the controller response.

Such methods are well known in the control art and broadly applied in the aerospace field. (9) (10)

The application of these techniques in the automotive brake control system required a massive effort in analysis, computer simulation and vehicle testing. In general, basic problems of system logic and structure were handled on the digital computer while system tuning and tolerance establishment was done by both analog simulation and car testing.

SYSTEM CONSIDERATIONS

The reasoning behind the selection of a two-wheel over a four-wheel anti-lock system has been discussed. Some discussion of the background for the choice of vacuum power rather than electrical or hydraulic power for the brake pressure modulator is appropriate, since the power steering system or the automatic transmission could have supplied oil under pressure, and the modern alternator electrical system could have furnished the required peak power. Vacuum power devices are intrinsically slow, have response characteristics which depend on piston position and displacement, and are bulky. Nevertheless, it was concluded that these disadvantages were outweighed by the much slower response and higher cost of an electrical modulator, and the coordination and installation engineering problems associated with a tie-in to the hydraulic steering or transmission systems. We also wished to retain flexibility to adapt the anti-lock system to cars without power steering or automatic transmissions. Having made this decision, we designed the control circuits for compatibility with modulator response characteristics which could be obtained within reasonable limits of complexity, cost and size. The design of the present Sure-Track system assures that no performance has been sacrificed because of the choice of vacuum actuation.

More difficult choices are associated with alternatives among directional stability, stopping distance, and the accommodation of off-tolerance or deteriorated foundation brakes.

Since maximum lateral force capability is obtained with a freely rolling wheel, some compromise in directional stability is inherent in braking to any significant slip level.

The accommodation of lateral variations in road friction requires that the wheel on the high friction surface roll sufficiently freely to assure that unstable attitude changes cannot develop. Incorporation of this capability into the control system again requires some compromise if satisfactory "split coefficient" stability is to be maintained. Finally, if satisfactory stopping distances are to be achieved on high friction surfaces, both wheels must be driven to a relatively high slip level. With unbalanced brakes, it is necessary that the brake pressure be allowed to remain at a high enough level that the underbraked wheel achieve adequate slip. The other wheel will of necessity be overbraked. The system must be capable of adjusting for this condition without the risk of undue loss of stability with normal brakes under "split coefficient" conditions.

It is thus clear that the selection of system parameters involves a series of compromises among mutually contradictory requirements, so that the overall performance delivered inevitably implies a number of value judgments.

Where tradeoffs between stopping distance and stability were involved, we biased the system slightly toward stability.

Where the subjective "feel" — that is, driver consciousness of system operation — conflicted with stopping distance or stability, we emphasized objective performance.

COMPONENT EVOLUTION

This part of the paper deals with the evolution of major components of the Sure-Track brake system. Figure 3 is a schematic of the system mounted on a vehicle chassis. Mechanically driven electro-magnetic sensors located in each rear wheel generate AC voltage pulses in proportion to wheel speed. These pulses are transferred through wiring to a solid-state electronic control module located under the glove box. The control module determines when a rear wheel skid is imminent and signals the vacuum powered brake actuator. This unit, located on the right frame rail near the rear of the engine, releases the rear brakes, then reapplies them when the wheels spin up.

Figure 4 shows early design sensors. One with teeth cut in the brake drum flange was discarded because of its vulnerability to damage. The next step was to put a rotating toothed ring and a stationary magnetic pick-up inside the brake. During this period of system development, when the control system was relatively unsophisticated, the

SURE-TRACK SYSTEM COMPONENTS

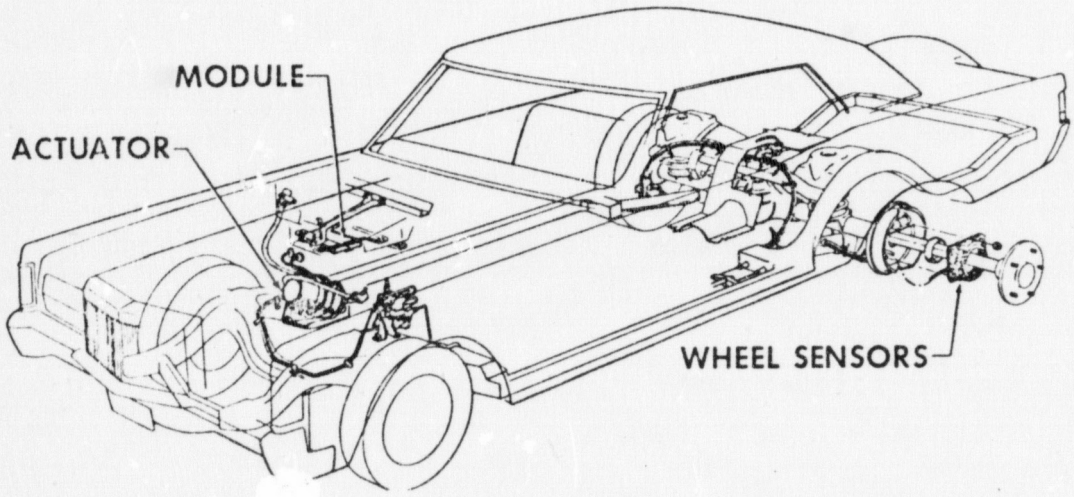

Figure 3

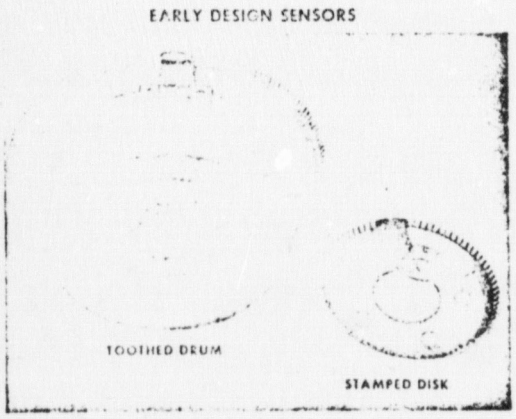

Figure 4

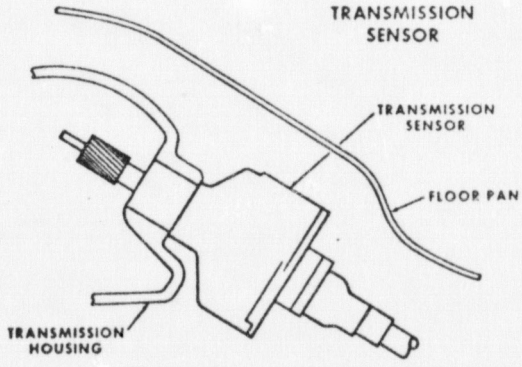

Figure 5

performance of this sensor seemed to be satisfactory. However, when a production design was made, axle and brake tolerances and deflections became a problem. In addition, the sensor ring was vulnerable to damage in service handling. These reasons, together with the desire to obtain the simplicity and cost saving that could result from using only one sensor, led to the next phase being centered around transmission output sensing.

One of the several designs considered is shown in Figure 5. This sensor was designed to attach to the transmission at the speedometer cable attaching boss, the speedometer cable being connected to the sensor. An integrated stator, rotor and bearing permitted minimum clearance between the rotor and stator so that a good signal was generated. However, backlash and vibration between the sensor and the rear tires created electrical noise which the module sometimes read as skid signals. Lash between the speedometer drive gear and the rotor gear was particularly troublesome. Attempts to pre-load the gears with cam adjustments and spring-loaded flexible shafts were unsuccessful and caused excessive tooth wear.

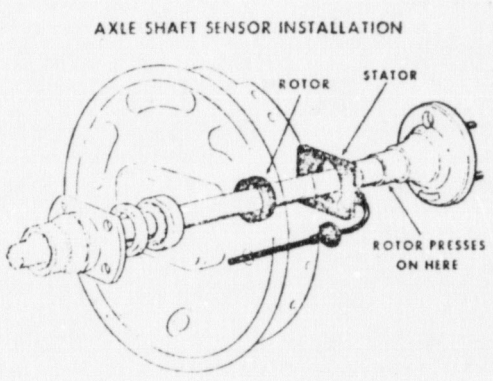

Figure 6

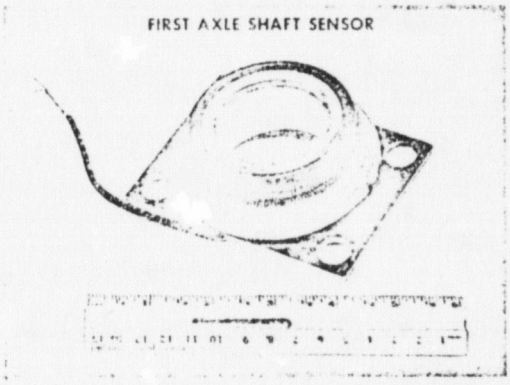

Figure 7

At this point small size wheel sensors appeared to offer the best solution. They were designed to be attached as shown in Figure 6. A special diameter was turned on the axle shaft outside of the wheel bearing on which the rotating member (rotor) was pressed. The wheel bearing outer retainer was replaced with a new, similar plate to which the stationary member (stator) was attached. The first design is shown in Figure 7. The rotating member consisted of a steel ring, a rotating circular magnet of barium ferrite suspended in a rubber compound, and a soft iron outer ring with 160 teeth on its outer diameter. The stationary member contained corresponding teeth and a coil. The design calculations indicated that the sensor would have sufficient output with the clearance required for production tolerances and axle deflections. However, the experimental components had much lower output than was expected, and unacceptably small tooth gaps were required for adequate signal strength. The rubber magnet also caused a problem due to distortion. Sensors set up with running clearance one day would have tooth interference the next day.

About this time the idea of a floating sensor was conceived. The first experimental design is shown in Figure 8. The rotating member has 130 teeth and is pressed onto the axle shaft. The stator contains the coil and magnet and is held against the wheel bearing retainer by 2 leaf springs. The components are dimensioned so that the smooth rub rings contact each other before the teeth make contact. Rub ring contact causes the stator to shift position on the retaining springs so that it becomes self-aligning, thus providing for manufacturing variations and axle deflections.

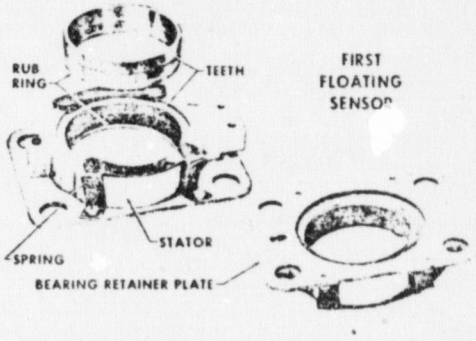

Figure 8

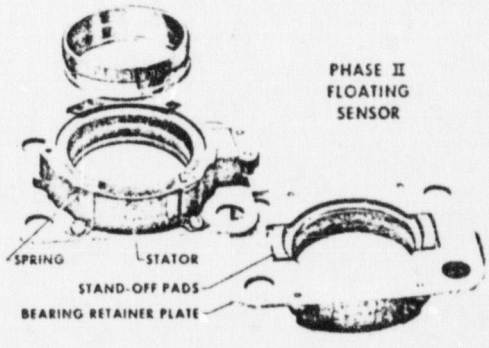

Figure 9

It was found that this design was subject to damage during installation. If one nut was run up ahead of the others before the axle shaft and bearing were completely seated, the bearing retainer might be bent so that the stator was significantly misaligned with the rotor. A design modification, as shown in Figure 9, was made, incorporating two stand-off pads or feet on the rub ring so that they contacted

the outer race of the wheel bearing and held the stator off the bearing retainer by .020 inches. This change gave good stator-rotor alignment, even when the retainer was distorted. It had a second advantage of providing essentially constant friction contact with the bearing in spite of retainer corrosion.

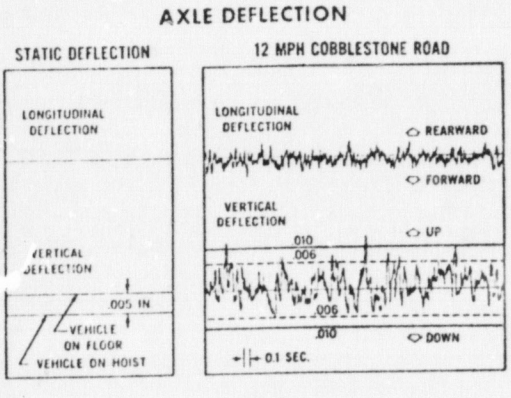

Figure 10

Car tests were conducted over various road surfaces to determine the relative motion between the rotor and stator. A typical tape is shown in Figure 10. It shows the vertical and longitudinal deflections of the axle shaft at the rotor with respect to the stator. In the static deflection chart shown at the left, note the shift of .005 inches in the center of rotation when the vehicle weight is put on the floor. With a fixed design sensor, clearance must be provided for this initial deflection, while the floating design merely shifts the stator to a new center. The dynamic portion of this tape, taken at 12 mph over a severe cobblestone road, shows a maximum deflection of ± .0125 inches, with most of the deflections less than ± .006 inches. Similar car tests were conducted on a variety of road surfaces and speeds. Other tests were made to determine the portion of time the rotating and stationary rub rings were in contact. These data were used to design laboratory tests which duplicated our rough road durability test procedure.

SENSOR WEAR TEST

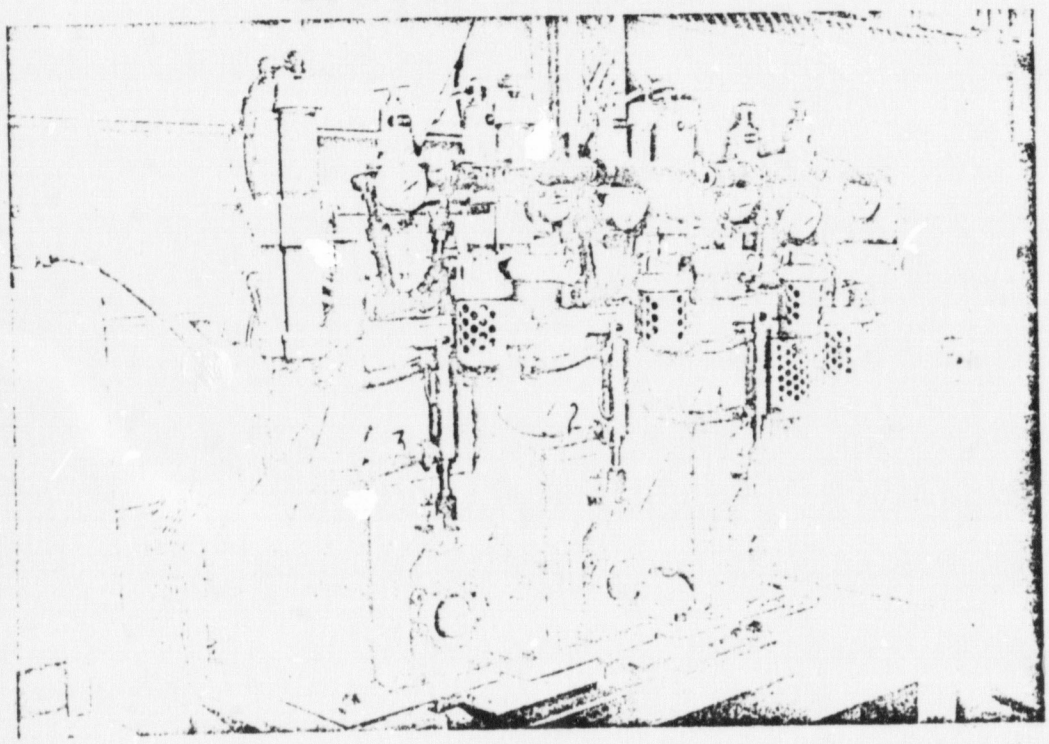

Figure 11

One of the test fixtures is shown in Figure 11. With this fixture, three sensors can be tested simultaneously for rub ring wear. The rotors are pressed onto the test fixture spindles, shown near the bottom, which are turned the equivalent of 45 mph. The stators are bolted to face plates, which are cycled up and down by hydraulically powered cylinders in a programmed frequency and amplitude, based on car data from the rough road course. Figure 12 shows the results of life tests on several materials. We would have preferred that the rotor be the more rapid wear member, but this was precluded by a combination of manufacturing and output signal considerations. The released stationary rub ring is moly-disulphide coated, tuftrided sintered iron, and the rotor rub ring is mild steel, chrome plated, and molydisulphide coated.

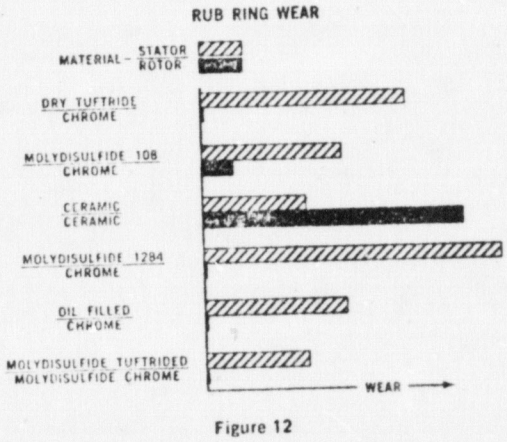

Figure 12

As development was continued, the system became more and more sophisticated so that the sensor signal quality became more important. It was found that sometimes, because of insufficient difference between the velocity signal and the noise signal generated by axle deflections, the control module could not identify the skid signal. Several design modifications were built and checked for useful and noise signals. Some of the results are shown in Figure 13. The control system is frequency-sensitive rather than amplitude-sensitive, so that the peak-to-peak amplitude of the signal is unimportant as long as the trace continues to cross the zero line. When it does not, as shown on the upper trace, the module reads it as wheel skid and fires the solenoid — a false signal. Finally, two major changes were made. The teeth were reduced from 130 to 65 and the magnetic material was changed from Alnico 5 to Alnico 6. The latter also resolved a manufacturing problem, in that Alnico 5 frequently cracked.

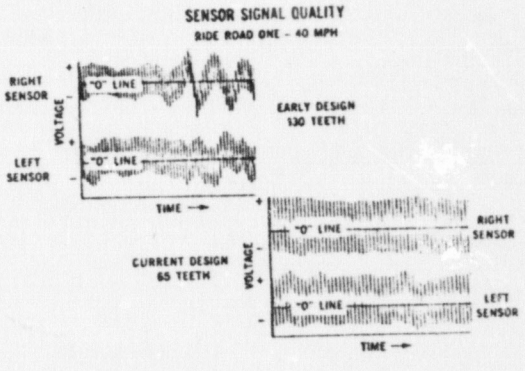

Figure 13

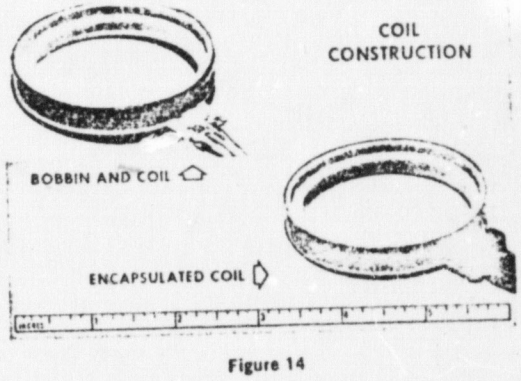

Figure 14

With the floating sensors, the coils were wound on nylon bobbins and the wire ends were soldered to metal terminals, as shown at the top of Figure 14. Later the lead wires were soldered to the terminals, then the stator components were put into the stator housing. With the initial design, the assembly was filled with a soft rubber-like potting. Because manufacturing equipment was not available, experimental sensors were filled with the potting material only at the terminal cavity. Several instances of wire failure were traced to motion within the potting material. Therefore, it was decided to encapsulate the coil and terminals in a more rigid material. Thermoset EL-798, a thermosetting epoxy, was selected. An encapsulated coil with its lead wires attached is shown on the bottom of Figure 14. The sensor, developed as described, was released and is in production.

Another laboratory development and proof test fixture is shown in Figure 15. It consists of 2 axle and driveshaft assemblies mounted in a test fixture. Weights, equivalent to the tire and wheel, are attached to each axle shaft flange. These and the brakes

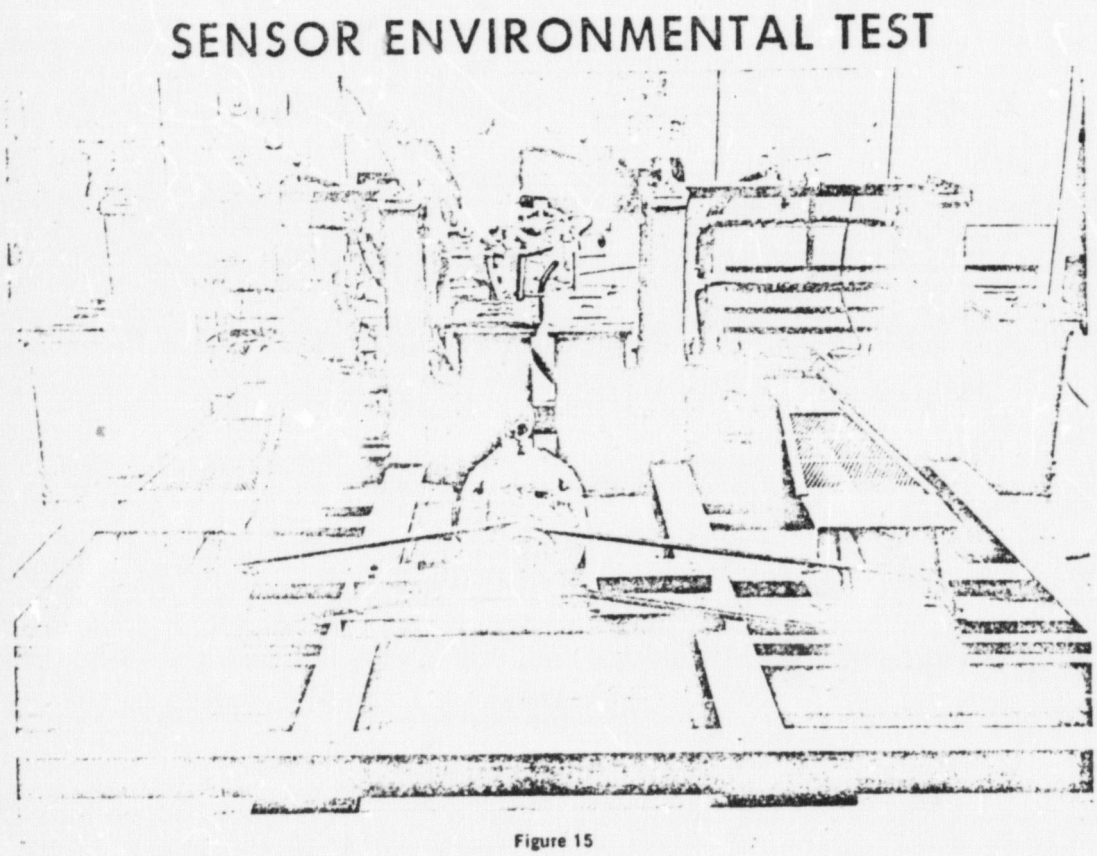

Figure 15

are then enclosed in the 4 environmental chambers shown. The propeller shafts are driven at the equivalent of 30 and 60 mph while air-powered cylinders raise and drop the axles to produce G loads in a programmed pattern based on measurements taken on the Ford rough road durability route. These shock-load and wear tests are conducted at ambient temperatures and at extremes ranging from -67F to + 350F. During the ambient life test, a mixture of brake lining dust and Arizona test dust is introduced inside the brake drum. Sensor output is measured at 4 mph and 100 mph before and after the test. Rub ring wear is measured at the completion of the test.

The control module was originally packaged integrally with the actuator so that the module and actuator could be attached to a common mounting bracket and pre-tested as an assembly prior to delivery to the assembly plant. This arrangement proved to be undesirable because of the environmental extremes imposed on the module. In addition, nothing was gained by a proof test of this assembly. Therefore, it was decided to locate the module inside the passenger compartment, either inside the left kick panel or under the glove box, as shown in Figure 16. The latter was released for production.

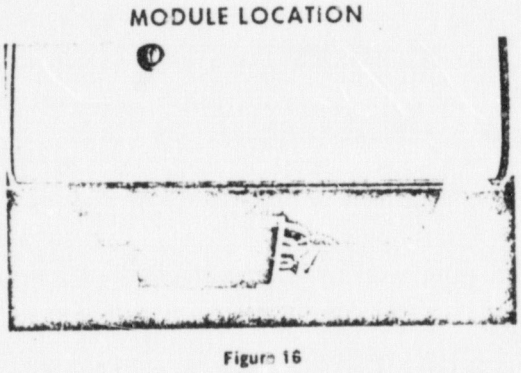

Figure 16

The development program revealed that it was relatively easy to design a module which performed satisfactorily down to .1 coefficient of friction. However, it required many hours of design considerations, computer analysis, and laboratory and car prove-out to develop a module which would self-adapt for road changes and give satisfactory performance on a complete spectrum of speed with friction coefficient from .05 up to dry concrete.

Performance requirements for the control module include input-output characteristics before, during, and after thermocycling at temperatures ranging from -67F to + 200F over a fifteen-day period. The automatic equipment for checking performance characteristics is shown in Figure 17. Other requirements pertain to vibration and impact resistance, established by measuring the loads imposed during car operation. It is interesting to note that the maximum impact load imposed on the control module occurred when the glove box door was slammed, which produced loads as high as 16.7 G. The specification we established requires satisfactory performance after 3½ hours of 30 to 40 G impacts of 10 to 15 milliseconds duration at the rate of one per second, and after smaller, varied, higher-frequency vibration loads for a period of one hour.

MODULE ENVIRONMENTAL TEST EQUIPMENT

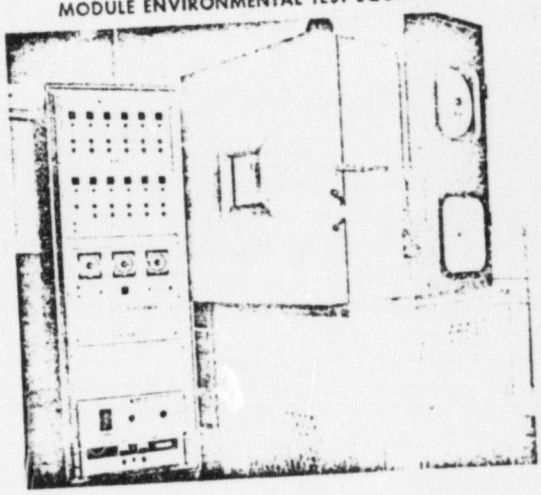

Figure 17

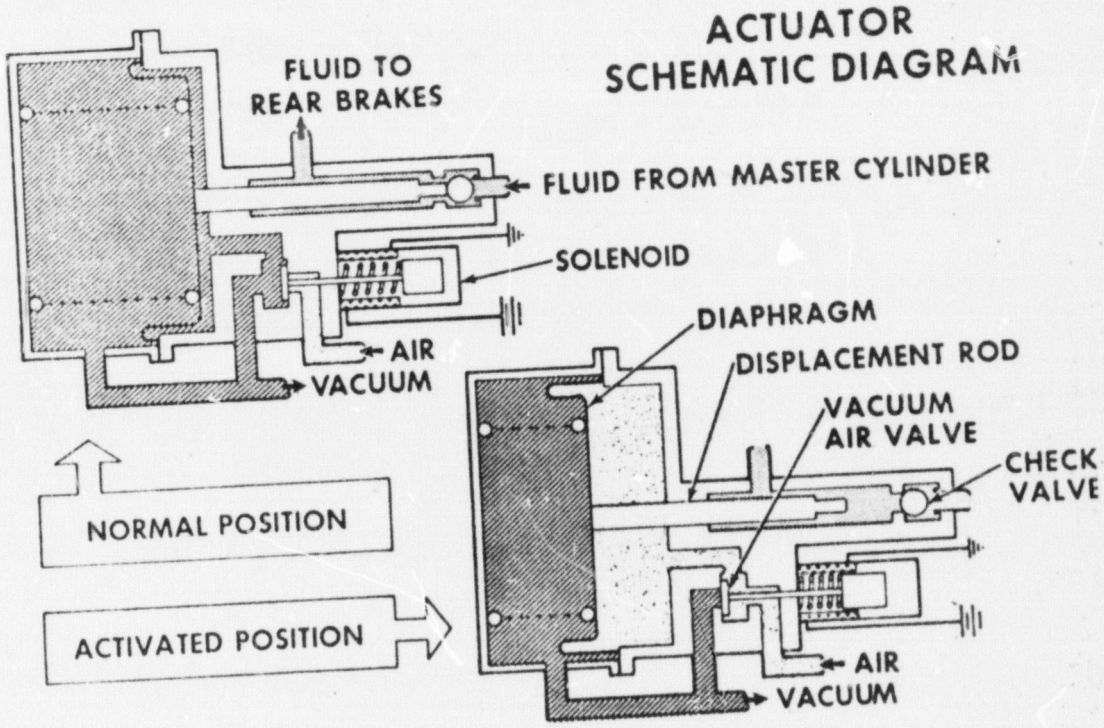

Figure 18

The brake actuator is vacuum-suspended, has a displacement-rod type hydraulic cylinder, and has a solenoid-operated vacuum-air valve. Figure 18 is a schematic showing how it operates. When a skid is imminent, a command from the control module causes the solenoid to close the vacuum passage to the right side of the diaphragm and to open it to atmospheric pressure. This causes the diaphragm and power plate assembly to move to the left compressing the return spring. Hydraulic pressure from the master cylinder acts on the end of the displacement rod and forces it to the left. The first short movement closes the check valve and isolates the master cylinder. Additional motion increases the volume for fluid thereby reducing the hydraulic pressure to the rear brakes so that they release. When the wheels spin up, the control module causes the solenoid to revert to its normal position. Vacuum is applied to both sides of the diaphragm and the return spring forces the power plate, diaphragm, and displacement rod to the right. This restores line pressure and reapplies the rear brakes.

Figure 19 shows an early design actuator. During the development program several design improvements were incorporated. Among them were better sealing against corrosion for the solenoid, improved

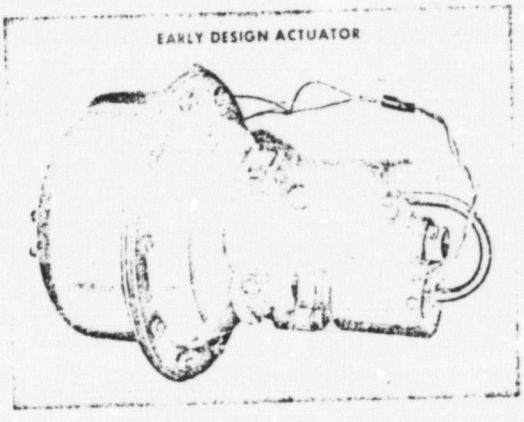

Figure 19

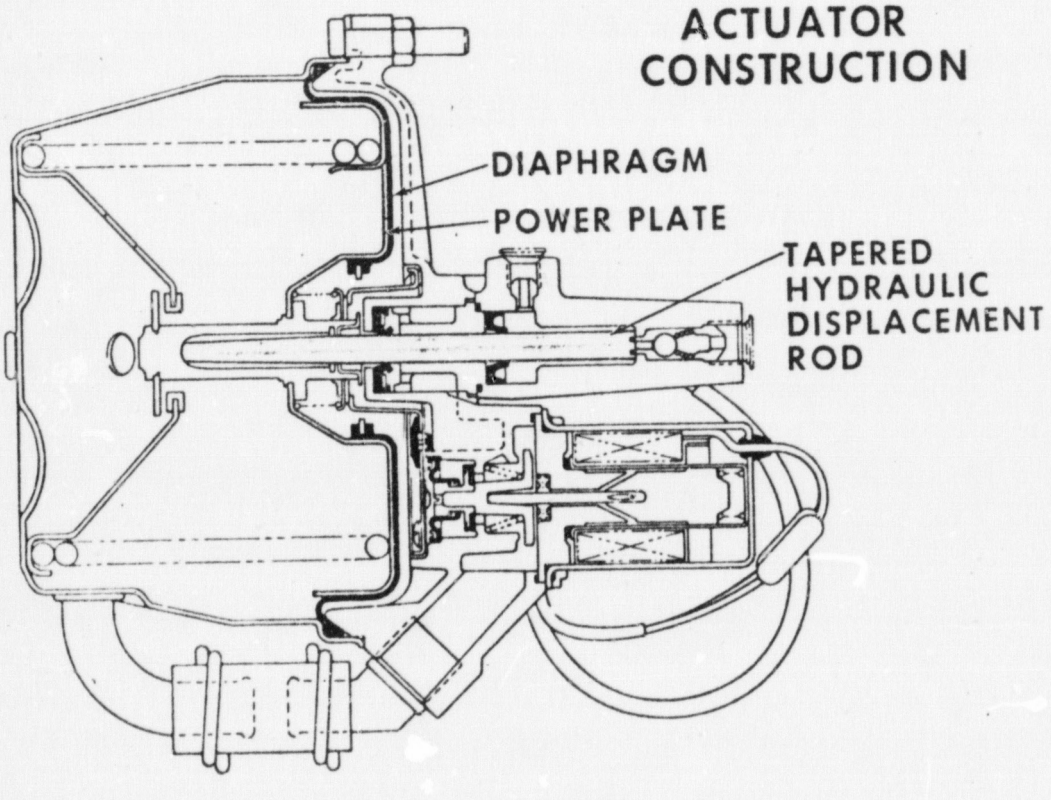

Figure 20

diaphragm clamping, and more free breathing. Even though no actuator was ever known to fail in the partially applied position, a position sensitive switch was added to warn of loss of rear brakes in the event such a failure occurred.

The released actuator design is depicted in Figure 20. Note that the power plate and diaphragm can move away from the displacement rod so that rapid cycling of the actuator cannot create a vacuum in the hydraulic system.

Originally the piston had straight sides and a spherical radius where it seats in the power plate. A taper was added to correct a bind problem that occurred after corrosion tests.

The early design actuator had pressure dump and build-up characteristics as shown at the left on Figure 21. Computer studies indicated that ideal wheel slip could be more nearly attained with a lower rate of pressure build-up as the cut-off pressure was approached, particularly on high friction surfaces. Since car tests confirmed this conclusion, the actuator response was changed to that shown at the right on Figure 21. The change in rate of pressure

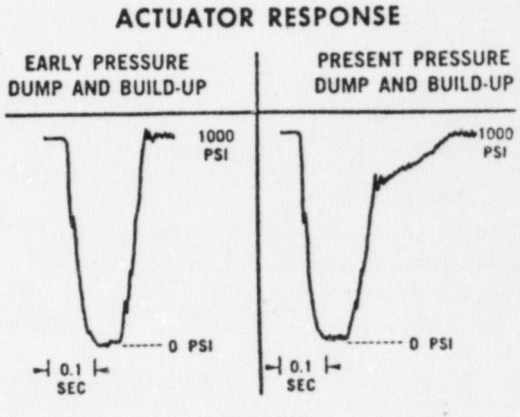

Figure 21

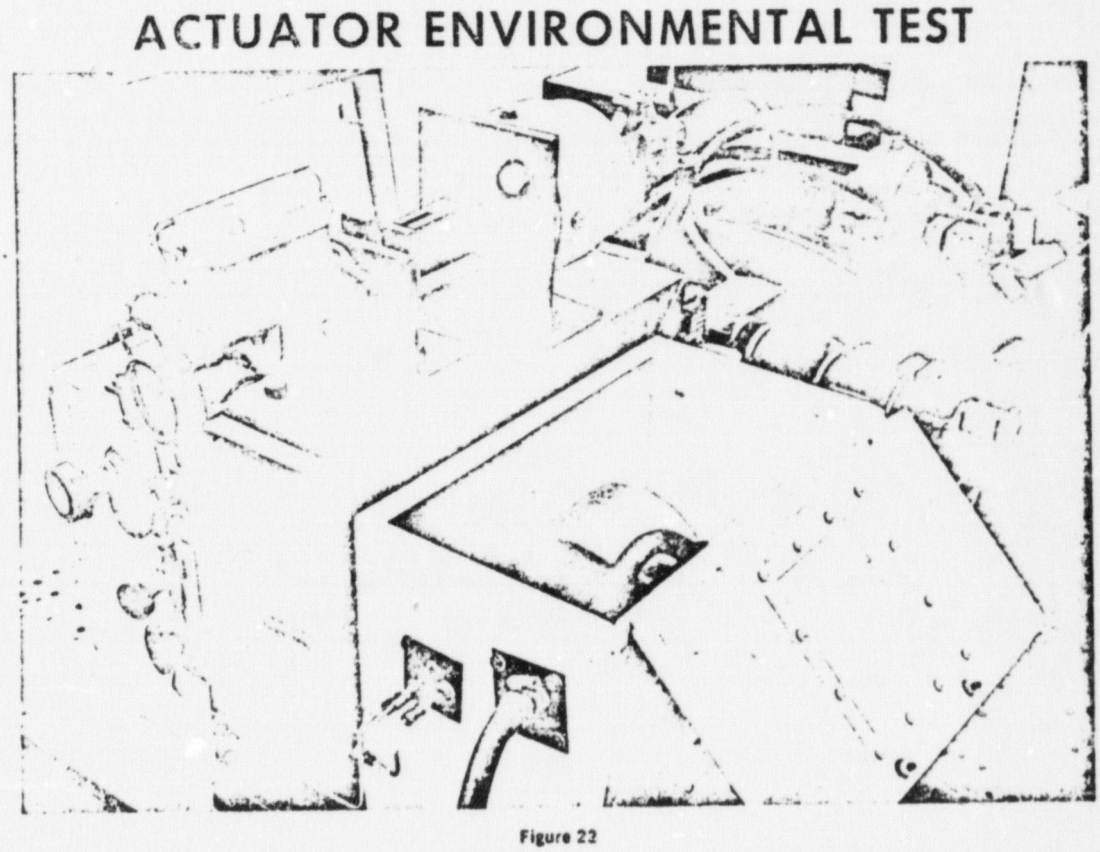

Figure 22

rise was achieved by the addition of a position-sensitive valve which restricted the vacuum passages.

Figure 22 shows part of the test set-up for actuator validation. The test actuator is mounted in the environmental chamber shown in the foreground. A pneumatically driven master cylinder applies brake fluid pressure cycling from 0 to 1000 psi. On the tenth application, the pressure is held while the actuator is cycled ten times. This sequence is repeated for a total of 500,000 static and dynamic cycles at ambient temperatures. Similar cycle and soak tests are conducted at temperature extremes ranging from a low of -67F to a high of + 280F. After each of these, the hydraulic and vacuum leakage and input-output response characteristics must be within prescribed limits.

Several locations were considered for the actuator. However, assembly plant processing problems dictated that the hydraulic system be attached to the chassis to permit brake system bleeding prior to front-end sheet metal decking. Therefore, the location on the right of the frame near the rear of the engine, as shown in Figure 23 was released. A large mounting bracket was developed cooperatively with assembly plant processing engineers to protect the actuator from damage during engine transmission decking and body decking.

SYSTEM PERFORMANCE

The performance objective set for the system was to improve vehicle yaw stability, with overall stop distance no greater than obtained with four-wheel lock. The performance was determined by making a series of spike stops on each test surface with the system "off-on-on-off" and repeating the sequence until an average or statistical comparison was possible. On high friction surface tests, it was also necessary to test in a prescribed speed sequence; otherwise, results were unreliable because the base brake system had some kind of "memory" when repeatedly subjected to the same high speed, high friction stops. In fact, when high friction stops were being made on several successive days, the brakes were mildly burnished each night to overcome this phenomenon.

The performance data taken between January and November, 1968, was recently reviewed to see how many "spike" stops had been made. The result was an amazing 15,000 plus.

A car, instrumented for performance test is shown in Figure 24. Recording instrumentation is

ACTUATOR MOUNTING

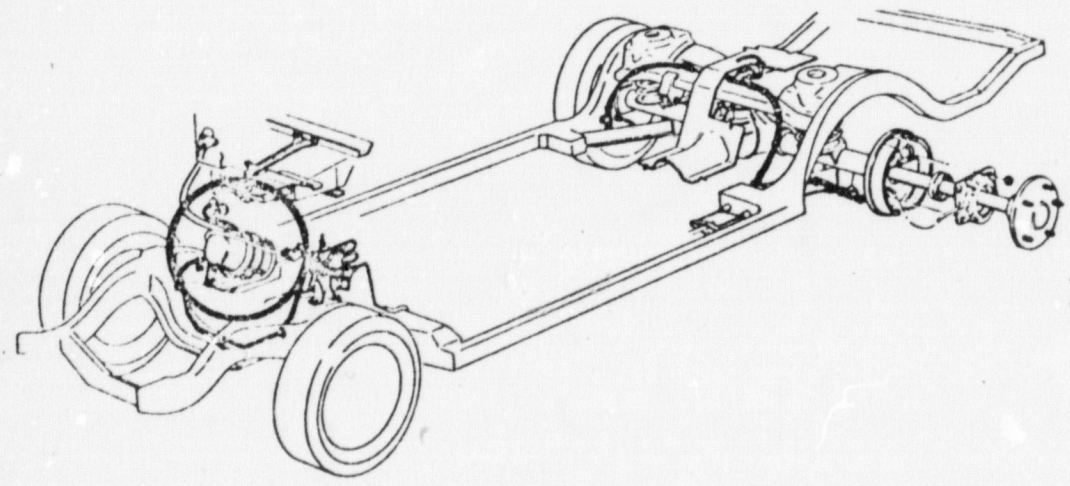

Figure 23

CAR INSTRUMENTED FOR TEST

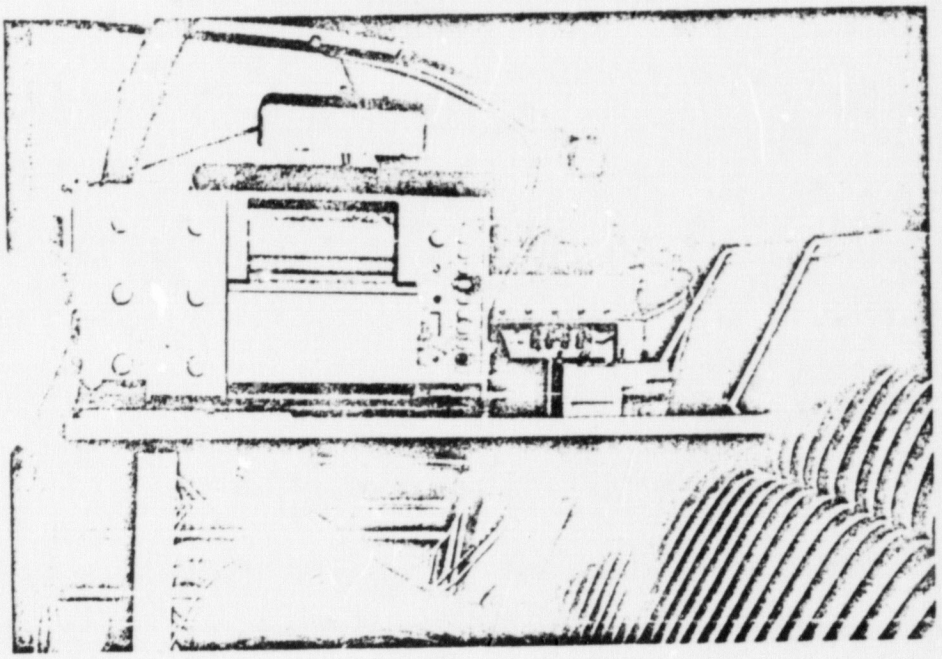

Figure 24

STOP DISTANCE MEASUREMENT

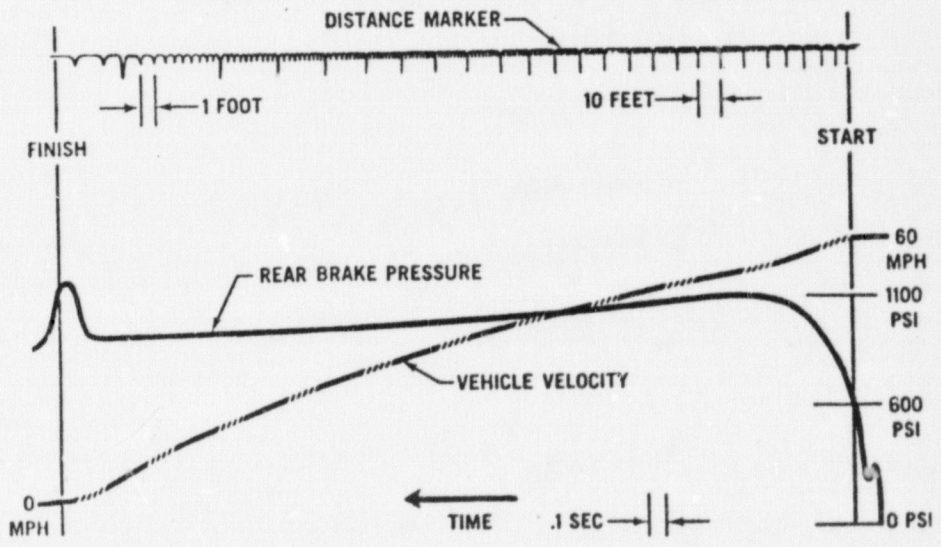

Figure 25

required to consistently determine the stop distance with reasonable accuracy. Figure 25 is a representation of the data that must be taken. Vehicle velocity is measured with a 5th wheel. Hydraulic pressure is measured for 2 reasons. It shows if the system being tested affects the rate of brake application and it gives a starting point for measuring distance. When the data is reduced, stop distance is measured to the closest .5 foot using the point where the line pressure reaches 600 psi as the "start-of-the-stop." This distance is then corrected based on the square of the desired initial velocity divided by the actual initial velocity measured to within .2 mph. The need for this accuracy becomes obvious when we consider that on a stop from 60 mph an error of 1 mph in speed, .2 seconds in point of application and 1 foot in distance add up to more than a 10% error in stop distance.

During most development tests additional data was taken so that the performance of the system could be evaluated. A typical tape is shown in Figure 26. The system is "off" (conventional brakes) at the top and "on" (Sure-Track system operational) at the bottom. In addition to the information previously mentioned these tapes show individual wheel velocity, vehicle deceleration, and the solenoid signal. Yaw is not shown here but was usually measured by means of a gyroscope and recorded on the same tape. When appropriate, other data such as manifold or actuator vacuum, front brake line pressure, sensor signal, and engine rpm were taken.

Friction surfaces ranging from dry concrete down to about .05 were available on the Ford proving grounds. The low friction was obtained by using Hydrolube and water on a plastic sheet. The validity of development tests on this surface was confirmed by tests on ice at Dearborn, International Falls, Minnesota and on the Olympic ice rink at Squaw Valley, Calif.

Almost any reasonable anti-lock system will show an improvement in vehicle yaw control, but it

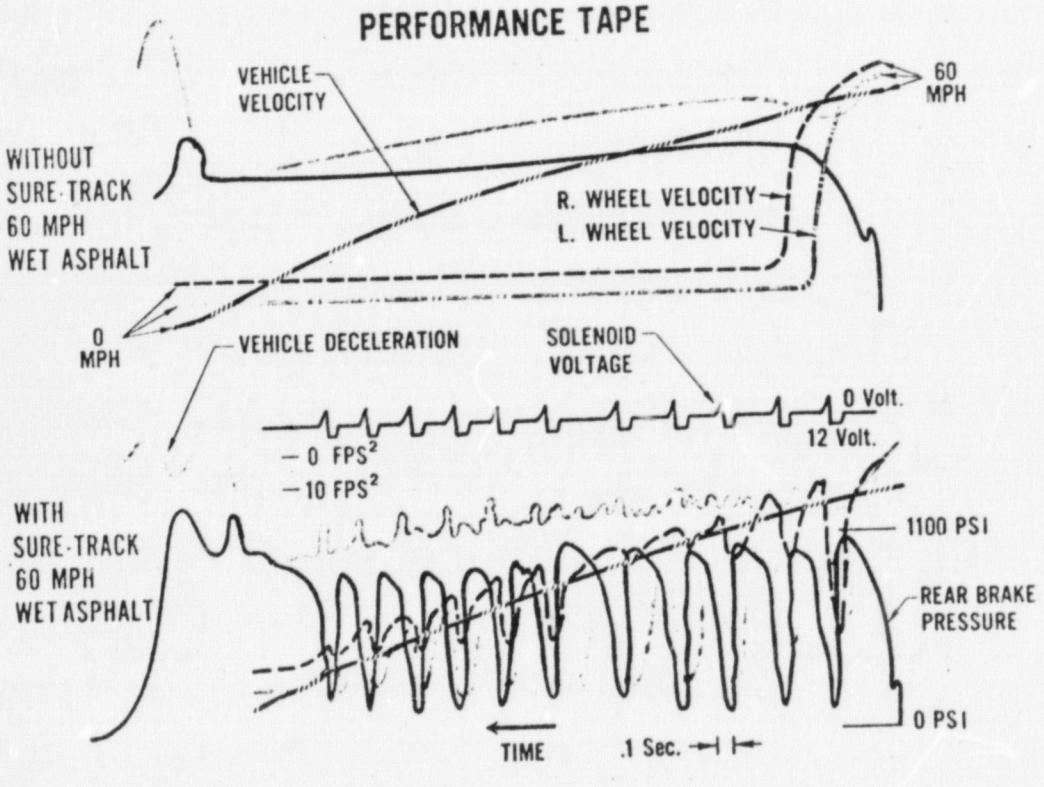

Figure 26

is extremely difficult to also reduce stop distances over wide ranges of speed and friction encountered in customer service. Figure 27 shows a statistical plot of yaw during 60 mph stops on wet asphalt with conventional and Sure-Track brakes. Similar data for 20 mph on Hydrolube is shown in Figure 28. While it is true that on a given stop any car may have relatively little yaw, these charts show that the Sure-Track system provides significant yaw reduction on an overall basis. Even more remarkable is the reduced yaw when stopping with high friction on one side of the car and low friction on the other. This significant improvement in yaw control is achieved with a system which also reduces the overall stop distance, compared to four-wheel lock, as shown in Figure 29.

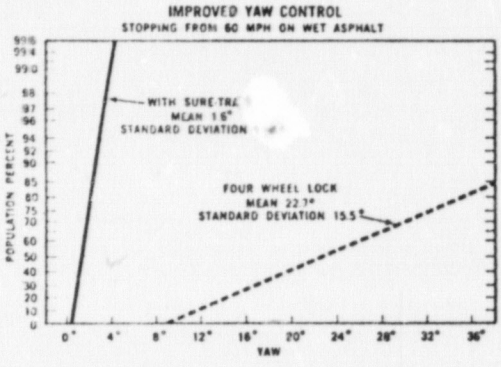

Figure 27

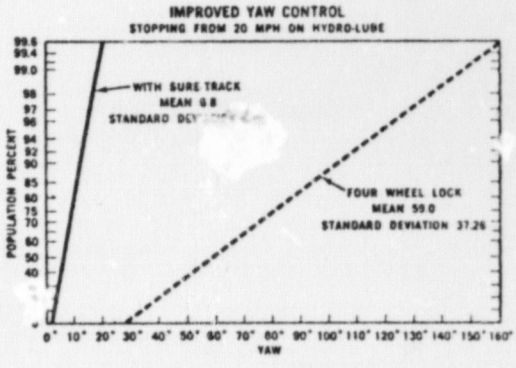

Figure 28

PERFORMANCE DATA

INITIAL SPEED MPH	MARK III					THUNDERBIRD				
	AVG. FRICTION	STOP DISTANCE FT.		YAW		AVG. FRICTION	STOP DISTANCE FT.		YAW	
		4-WHEEL LOCK	SURE-TRACK	4-WHEEL LOCK	SURE-TRACK		4-WHEEL LOCK	SURE-TRACK	4-WHEEL LOCK	SURE-TRACK
10	.07	47.6	48.3	4	3	.05	66.0	68.6	5	3
18	.07	152.8	148.2	6	4	.05	197.0	200.3	10	6
20	.21	62.6	55.4	4	2	.21	63.6	58.3	7	2
30	.16	187.1	163.8	6	2	.16	186.8	170.6	11	3
20	.83	15.9	16.8	1	1	.71	18.7	19.4	2	1
40	.66	80.4	80.8	7	2	.56	91.7	91.7	4	2
60	.51	233.4	213.6	29	2	.47	251.7	234.6	23	2
20	.80	16.5	16.9	2	1	.83	15.9	16.0	2	1
40	.74	71.8	71.4	5	1	.75	70.4	71.6	8	2
60	.72	164.1	166.8	15	2	.71	166.4	163.5	15	2

SPLIT FRICTION PERFORMANCE WITH SURE-TRACK SYSTEM*

SPEED MPH	SURFACE FRICTION	MARK III			THUNDERBIRD		
		YAW ANGLE			YAW ANGLE		
		MIN.	MAX.	AVG.	MIN.	MAX.	AVG.
25	RIGHT .85 LEFT .25	5	30	17.8	6	45	20.7

*RIGHT SIDE WHEELS ON 0.85 FRICTION SURFACE
LEFT SIDE WHEELS ON 0.25 FRICTION SURFACE
WITH 4-WHEEL LOCK, YAW ON SPLIT COEFFICIENT SURFACE EXCEEDED 90 DEGREES IN ALL CASES

Figure 29

The upper portion of Figure 29 shows average distances with 4-wheel lock and Sure-Track under a wide range of friction and vehicle speed conditions. Regular production tires were used on these tests, including determination of the coefficient of friction. The procedures previously described were used in determining the stop distances. As previously indicated, the yaw improvement due to Sure-Track is remarkable. On extremely low friction surfaces, such as ice, and high friction surfaces such as dry pavement, 4-wheel lock and Sure-Track stop distances are essentially equivalent. However on moderately low friction surfaces and at 60 mph on medium friction surfaces, the reductions in stop distance due to Sure-Track are impressive.

The lower portion of the chart shows the benefit of improved vehicle stability when making panic stops with significantly different friction on the two sides of the car. This is equivalent to making panic stops with the 2 wheels on one side of the car on snow and the two on the other side on clear pavement. With 4-wheel lock the car goes out of control and yaws more than 90 degrees in all such stops, while with Sure-Track yaw is significantly reduced even under these extreme conditions.

SUMMARY

The use of anti-lock braking system on aircraft led to efforts to adapt such a system to road vehicles, or to develop a unique system. Experimentation with several systems led to a set of requirements necessary for feasible vehicle anti-lock system development. Refinement of one particular system led to its introduction as an option early in the 1969 model year.

More than 15,000 on-the-road braking tests plus laboratory and computer analysis of pre-production units have assured attainment of system reliability, manufacturing feasibility, and substantially improved braking performance. Road tests have shown that yaw stability during panic braking is controlled to close limits under all conditions and that stopping distance is the same or less in most braking situations, regardless of the coefficient of friction of the road surface or speed at the time brakes are applied.

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6. H. W. Kummer & W. E. Meyer, "Measurement of Skid Resistance," Special Tech. Publication No. 326, Symposium on Skid Resistance ASTM, 1962.
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PLAINTIFF'S EXHIBIT 122

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF NEW YORK

PERMA RESEARCH & DEVELOPMENT COMPANY,

Plaintiff,

-against-

THE SINGER COMPANY,

Defendant.

66 Civ. 665

PLAINTIFF'S PRE-TRIAL MEMORANDUM

Plaintiff submits as "Plaintiff's Pre-Trial Memorandum", pursuant to the requirements of Calendar Rule 14 of the Rules of this Court and of the order of Chief Judge Sidney Sugerman, dated April 29, 1971, the following:

Introduction

The attorneys for plaintiff, Perma Research & Development Company ("Perma"), and defendant, The Singer Company ("Singer"), met and conferred on September 23, 1971. At that meeting, the parties were unable to reach agreement concerning the facts and issues to be litigated; defendant's position as stated at that meeting was that only after plaintiff presents its case in court and only after plaintiff's case withstands a motion for a directed verdict will defendant then select the aspects of plaintiff's case which it will dispute.

Plaintiff believes that the decisions of Judges Frederick Van Pelt Bryan, Floyd F. MacMahon and Charles M. Metzner on three motions for summary judgment and one for reargument made by defendant have eliminated a large number of potential issues

(c) Defendant failed to utilize available collaboration with plaintiff.

5. Further Narrowing of Issues for Trial

Judge MacMahon's opinion identified the principal issue for trial as "whether Singer did use its best efforts for a reasonable length of time in collaboration with Perma to perfect the product in order to be in a position to market it." (Perma v. Singer, 308 F.Supp. at 749.) While marketing could not be commenced until a number of problems were solved, Singer viewed the "fail-safe" problem as the principal one. The "fail-safe" problem, as described by Singer in 1965 was that if the device failed, it could possibly impair the operation of the automobile brakes and possibly result in an accident. Two Courts have previously found that it was because of the "fail-safe" problem that Singer abandoned the contract in 1965. Perma v. Singer, 66 Civ. 665 (SDNY, March 29, 1968), at page 4; Perma v. Singer, 410 F.2d, 572, 574 (2nd Cir. 1969). Plaintiff submits that these decisions establish the law of the case and that, accordingly, the pre-trial order should limit the issues for trial to the following specific question:

> "Did Singer use its best efforts, for a reasonable period of time, in collaboration with Perma to make the invention 'fail-safe'?"

In the event this Court does not agree that the issues can so be narrowed, the problems against which Singer's "best efforts" are to be measured can be no broader than those stated by Singer in 1965 to be ones which caused it to abandon the contract.*

*It should be noted that it is plaintiff's position that neither the existence of the problems enumerated below nor the inability to solve them economically caused Singer to abandon this contract. According to defendant's own estimate, they could have been solved

In addition to the "primary" fail-safe problem, those claimed by defendant at the time were:

(a) engine stalls resulted in vacuum loss and brake line pressures below specifications;

(b) vacuum at slow automobile speeds was inadequate to prevent slight lag in operation of invention;

(c) the unit could be "fooled"; and

(d) reliability testing of the invention and its components was not complete.

In other words, whether Singer used its "best efforts" under the contract must be determined by whether it did so with respect to those problems which in 1965 it claimed led it to abandon the contract. It would be manifestly unfair to allow defendant now to raise other problems not claimed as such prior to this litigation.

A complete trial of all the reasons set forth above would require several weeks and masses of technical engineering detail. Plaintiff submits that the differences between the parties can be fully and fairly tried on the question of fail-safety and that a trial so limited will substantially conserve the time of this Court.

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at a cost of between $300,000. and $1,000,000. - a small cost for a product of this nature. Defendant abandoned the contract because its principal executives decided for the first time, months after entering the contract, that defendant should not be in the business of supplying safety devices to the automobile industry, involving products distinctly different from defendant's other products, with possible product liabilities and competitive risks to Singer not previously encountered by it. These grounds could have properly been the basis for a decision not to enter the December contract, but after defendant entered it, they could not properly provide justification for Singer's abandoning the contract. It is plaintiff's position that these were the real reasons for defendant's abandonment and that defendant wholly failed to use its best efforts to perform the contract.

UNITED STATES DISTRICT COURT

SOUTHERN DISTRICT OF NEW YORK

PERMA RESEARCH AND DEVELOPMENT COMPANY,	:	
Plaintiff,	:	66 Civ. 665
-against-	:	Cal. No. 97(2) (ECM)
THE SINGER COMPANY,	:	
Defendant.	:	

ADDITIONAL REASONS RENDERING THE PERMA ANTI-SKID DEVICE UNMARKETABLE

Pursuant to the proceedings at the pretrial conference in the above matter, held July 5, 1972, before the Hon. Edward C. McLean, U.S.D.J., set forth below are the additional reasons rendering the Perma anti-skid device unmarketable.

Defendant claims that the Perma anti-skid device was not marketable and could not reasonably have been made marketable on the following grounds (such grounds being in addition to those specified by plaintiff in its proposed Supplemental Pretrial Order dated July 19, 1972):

A. Perma consistently declined to admit that there were problems precluding the marketing of the device other than Singer's quality control and therefore failed to collaborate adequately with Singer in attempting to solve such other problems.

B. The Perma anti-skid device was defective in that the basic concepts underlying its operation precluded it from

being an effective anti-skid means. The basic concepts underlying the operation of the Perma anti-skid device were defective in the following ways:

1. The system was not fail-safe.

2. The system used a mechanical sensor which was insensitive and unreliable.

3. The system used a centrifugal speed governor as a sensor, although the wheel speed which the governor sensed had no relationship to wheel braking requirements.

4. The sensor was driven by a speedometer drive and cable which was not designed to carry such additional loads, and also produced erroneous signals due to the flexibility and clearances of the many parts involved.

5. The system used two sensing systems: a centrifugal speed governor and a rotational inertia deceleration sensor having a complicated interaction, which inherently increased the possibility of failure.

6. The system controlled all four wheels of the vehicle from a single sensor, ignoring the effect of weight transfer between the front and rear wheels of an automobile during braking.

7. The Perma sensing unit lacked capability for sensing differing road conditions and adjusting performance to such variable conditions.

8. The system used a single brake pressure modulating device (Perma-Vac) for all brakes on the vehicle in violation of certain state legislation mandating split braking systems.

9. The operation of the Perma system depended upon the performance characteristics of the vehicles in which it

was installed, which performance characteristics were not reasonably available and could not reasonably be developed.

10. The Perma system could not, as intended by the inventor, be safely and properly integrated into the different braking systems of a broad variety of vehicle makes and models under the range of environmental and brake system conditions reasonably to be expected.

11. The Perma system could not produce, under all road conditions, stopping distances equal to or shorter than stopping distances of vehicles not equipped with the system.

12. In the Perma system, the amplitude of pressure variation in the brakes during operation of the system was too high, causing unacceptable freewheeling periods and alternate periods of wheel locking.

13. The system's cycling frequency was inherently too low.

14. The system required a change in driver habits.

C. 1. Installation of the device on vehicles by persons other than the original manufacturers of the vehicles resulted in unreasonable hazards to the users of the vehicles.

2. Installation of the system involved altering the manufacturer's original braking system so as to create unreasonable risks that the vehicle manufacturer's warranty protection of the purchaser would be destroyed.

D. Even assuming that the underlying concept of the Perma system could have resulted in a device with a suitable anti-skid function, there were the following defects relating to the Perma system which could not reasonably have been cured:

1. The system used obsolete component types which had long been abandoned by vehicle manufacturers, as for example:

(a) Use of sliding members rather than flexible diaphragms, as in the construction of the Perma-Vac, the transfer valve and the pressure switch; and

(b) Use of rotary valves and sliding valves rather than poppet valves.

2. The testing of system components by Perma at the time Singer entered the December contract was so inadequate that:

(a) Component design and specifications could not reasonably be determined;

(b) Performance criteria for the Perma device could not reasonably be determined;

(c) Performance criteria of the system and its relation to vehicles could not reasonably be obtained; and

(d) Such automotive industry criteria for anti-skid performance as were known to Singer could not reasonably have been met within the configuration of the Perma design.

3. The selection of materials for the Perma system had been made by Perma with apparent disregard for the performance characteristics of those materials under reasonably forseeable conditions in an automobile.

4. The Perma-Vac component used an atmosphere suspended system, resulting in unacceptably long response time for the pressure modulator.

5. There was no vacuum reservoir for emergency purposes.

6. The design of the pressure switch inherently produced a large dead-band, namely a great difference between opening and closing pressures.

7. The design of the pressure switch resulted in wide variations in opening pressures in successive operations of the switch.

8. The system had no provision for either lifetime or periodic lubrication.

9. Installation of the Perma device in many vehicle types and models proved unreasonably difficult and time consuming.

10. System component design made repair and maintenance unreasonably difficult and expensive.

11. The need for extensive redevelopment of the Perma system reasonably indicates that, even if such redevelopment were successful, the cost of the Perma system would be so high as to be prohibitive to the ultimate user, thus rendering the Perma device unmarketable.

Dated: New York, New York
October 6, 1972

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PLAINTIFF'S EXHIBIT 123

Simulation of Perma Anti-Skid Device

Threshold .92g

Pressure switch setting:	Opens	Closes
in footpounds	150	250
in PSI (approximately)	115	159

Gear Ratio 24:1

Surface Coefficient of Friction	Speed	With	Without	Distance in feet
.75	60	158.5		160.8
	25	29.7		29.3
. 7	60	168.1		171.2
	40	77.0		77.9
	25	31.3		31.2
. 5	60	174.4		180.7
	25	28.9		29.1
. 2	35	171.0		195.6
	25	87.2		101.4
	15	32.1		36.8
.15	25	124.6		134.6
	20	79.0		86.8
	15	43.4		49.1

[PX 123, p 1]

PLAINTIFF'S EXHIBIT 124

Simulation of Perma Anti-Skid Device

Threshold .92g

Pressure switch settings:	Opens	Closes
in footpounds	150	250
in PSI (approximately)	115	159

Gear Ratio 12:1

Surface Coefficient of Friction	Speed	With (Distance in Feet)	Without (Distance in Feet)
.75	60	158.3	160.8
	25	31.3	29.3
.7	60	167.1	171.2
	40	78.6	77.9
	25	32.9	31.2
.5	60	172.8	180.7
	25	30.8	29.1
.2	35	172.1	195.6
	25	89.5	101.4
	15	32.6	36.8
.15	25	120.0	134.6
	20	77.0	86.8
	15	44.9	49.1

PLAINTIFF'S EXHIBIT 125

Simulation of Perma Anti-Skid Device

	Opens	Closes
Threshold .92g		
Pressure Switch Setting:		
in footpounds	150	250
in psi (approximately)	115	159
Gear Ratio 18:1		

Surface Coefficient of Friction	MPH Speed	With Distance in Feet	Without Distance in Feet
.75	60	157.7	160.8
	25	29.8	29.3
.7	60	166.9	171.2
	40	77.5	77.9
	25	31.5	31.2
.5	60	174.1	180.7
	25	29.3	29.1
.2	35	167.4	195.6
	25	83.3	101.4
	15	32.8	36.8
.15	25	122.9	134.6
	20	78.0	86.8
	15	43.6	49.1

[PX 125, p 1]

PLAINTIFF'S EXHIBIT 127
(FIRST THREE STOPS)

Simulation of Perma Anti-Skid Device

Threshold .92g

Pressure switch setting:	Opens	Closes
in footpounds	150	250
in PSI (approximately)	115	159

Gear Ratio 24:1

Surface Coefficient of Friction	Speed	With	Without	Distance in feet
.75	60	158.5		160.8
	25	29.7		29.3
.7	60	168.1		171.2
	40	77.0		77.9
	25	31.3		31.2
.5	60	174.4		188.2
	25	28.9		29.1
.2	35	171.0		195.6
	25	87.2		101.4
	15	32.1		36.8
.15	25	124.6		134.6
	20	79.0		86.8
	15	43.4		49.1

3000.	4.0	5.9	24.0	98.6	.030	.020	.030	0.51	0.39	250.0	150.0	0.92	700.	.344	20.0	.75				
0.000	0.0	88.00	0.05	0.0	88.00	0.00	0.000	88.00	0.00	0.000	0.0	88.00	0.00	0.000	88.00	0.00	0.000			
0.050	4.4	87.68	0.37	663.6	84.06	-3.03	0.041	84.06	-3.03	0.041	398.2	85.14	-2.28	0.029	85.14	-2.28	0.029			
0.100	8.8	86.97	0.61	1180.4	78.55	-3.98	0.096	78.55	-3.98	0.096	510.2	82.60	-1.45	0.049	82.60	-1.45	0.049			
0.150	13.1	86.76	0.71	1502.9	68.80	-9.82	0.198	68.80	-9.82	0.198	602.2	79.99	-1.80	0.068	79.99	-1.80	0.068			
0.200	17.3	86.61	0.74	1696.3	46.49	-17.53	0.450	46.49	-17.53	0.450	666.9	56.75	-2.27	0.093	6.75	-2.27	0.093			
0.250	21.5	86.39	0.76	2140.5	13.40	-23.36	0.839	13.40	-23.36	0.839	717.3	72.38	-3.35	0.133	72.38	-3.35	0.133			
0.300	25.7	82.16	0.77	2330.6	0.0	0.0	1.000	0.0	0.0	1.000	756.6	64.87	-6.04	0.211	64.87	-6.04	0.211			
0.350	29.8	80.92	0.78	2478.7	0.0	0.0	1.000	0.0	0.0	1.000	787.1	53.35	-8.16	0.341	53.35	-8.16	0.341			
0.400	33.9	79.65	0.80	2594.0	0.0	0.0	1.000	0.0	0.0	1.000	810.9	39.03	-9.53	0.510	39.03	-9.53	0.510			
0.450	37.7	78.35	0.82	2683.8	0.0	0.0	1.000	0.0	0.0	1.000	829.5	23.03	-10.27	0.706	23.03	-10.27	0.706			
0.500	41.6	77.02	0.84	2711.9	0.0	0.0	1.000	0.0	0.0	1.000	835.3	6.25	-10.31	0.919	6.25	-10.31	0.919			
0.550	45.4	75.66	0.87	568.7	20.12	33.43	0.734	20.12	33.43	0.734	341.2	2.11	4.27	0.972	2.11	4.27	0.972			
0.600	49.2	74.31	0.69	1445.9	69.58	-5.85	0.064	69.58	-5.85	0.064	573.9	11.65	-1.52	0.843	11.65	-1.52	0.843			
0.650	52.8	72.91	0.92	1501.6	57.26	9.05	0.215	57.26	9.05	0.215	585.4	4.61	-1.25	0.937	4.61	-1.25	0.937			
0.700	56.5	71.87	0.57	1109.6	68.94	-7.59	0.041	68.94	-7.59	0.041	504.5	11.05	2.39	0.846	11.05	2.39	0.846			
0.750	60.0	70.53	0.89	2447.2	46.70	-22.06	0.338	46.70	-22.06	0.338	780.6	6.92	-4.75	0.902	6.92	-4.75	0.902			
0.800	63.5	69.11	0.88	1201.7	58.50	12.67	0.154	58.50	12.67	0.154	523.6	9.82	3.20	0.858	9.82	3.20	0.858			
0.850	66.9	67.73	0.83	2372.7	35.90	-24.65	0.470	35.90	-24.65	0.470	765.3	6.75	-3.71	0.900	6.75	-3.71	0.900			
0.900	70.3	66.41	0.81	1667.4	37.41	-6.05	0.437	37.41	-6.05	0.437	619.7	9.64	0.46	0.855	9.64	0.46	0.855			
0.950	73.6	65.16	0.75	1449.9	5.84	-3.95	0.910	5.84	-3.95	0.910	574.8	6.16	1.24	0.905	6.16	1.24	0.905			
1.000	76.8	63.96	0.72	2174.4	0.27	-26.27	0.996	0.27	-26.27	0.996	724.3	8.31	-3.30	0.870	8.31	-3.30	0.870			
1.050	80.0	62.81	0.72	963.9	4.33	8.15	0.931	4.33	8.15	0.931	474.5	8.40	3.59	0.866	8.40	3.59	0.866			
1.100	83.1	61.67	0.70	1508.1	0.0	0.0	1.000	0.0	0.0	1.000	586.8	6.19	0.08	0.900	6.19	0.08	0.900			
1.150	86.1	60.53	0.71	2029.9	0.0	0.0	1.000	0.0	0.0	1.000	694.5	8.13	-3.04	0.866	8.13	-3.04	0.866			
1.200	89.1	59.39	0.72	1064.1	5.48	6.15	0.908	5.48	6.15	0.908	495.2	8.50	2.65	0.857	8.50	2.65	0.857			
1.250	92.1	58.23	0.72	1291.5	0.00	0.07	1.000	0.00	0.07	1.000	542.1	6.39	1.20	0.890	6.39	1.20	0.890			
1.300	95.0	57.04	0.74	2073.0	0.0	0.0	1.000	0.0	0.0	1.000	703.4	7.58	-3.36	0.867	7.58	-3.36	0.867			
1.350	97.8	55.82	0.78	1306.5	8.04	1.34	0.842	8.04	1.34	0.842	561.7	8.81	0.78	0.842	8.81	0.78	0.842			
1.400	100.5	54.58	0.78	1046.5	1.87	11.73	0.966	1.87	11.73	0.966	491.5	6.80	2.67	0.875	6.80	2.67	0.875			
1.450	103.2	53.29	0.80	1958.1	2.65	-12.72	0.950	2.65	-12.72	0.950	679.7	6.87	-2.78	0.871	6.87	-2.78	0.871			
1.500	105.9	51.96	0.85	1701.4	14.80	-1.90	0.715	14.80	-1.90	0.715	626.7	8.67	-1.24	0.833	8.67	-1.24	0.833			
1.550	108.4	50.60	0.87	856.9	17.30	24.01	0.658	17.30	24.01	0.658	452.4	7.57	3.55	0.851	7.57	3.55	0.851			
1.600	110.9	49.17	0.90	1541.4	26.40	7.17	0.463	26.40	7.17	0.463	593.7	6.32	-0.83	0.872	6.32	-0.83	0.872			
1.650	113.3	47.85	0.84	1782.6	43.40	-4.04	0.093	43.40	-4.04	0.093	643.4	8.06	-2.16	0.832	8.06	-2.16	0.832			
1.700	115.7	46.64	0.54	924.8	44.89	-2.46	0.038	44.89	-2.46	0.038	466.4	8.46	3.16	0.819	8.46	3.16	0.819			
1.750	118.0	45.29	0.87	1345.0	40.77	9.45	0.100	40.77	9.45	0.100	553.1	6.17	0.65	0.864	6.17	0.65	0.864			
1.800	120.2	44.16	0.9	2002.7	38.18	-7.49	0.136	38.18	-7.49	0.136	705.4	8.12	-3.14	0.816	8.12	-3.14	0.816			
1.850	122.4	42.85	0.60	112.0	40.76	-3.73	0.049	40.76	-3.73	0.049	505.0	8.63	2.82	0.798	8.63	2.82	0.798			
1.900	124.5	41.51	0.87	45.2	29.43	6.84	0.291	29.43	6.84	0.291	573.8	6.30	0.74	0.848	6.30	0.74	0.848			
1.950	126.6	40.24	0.86	2153.4	32.28	-13.93	0.198	32.28	-13.93	0.198	720.0	8.06	-3.23	0.800	8.06	-3.23	0.800			
2.000	128.5	38.90	0.70	1171.7	35.96	2.07	0.076	35.96	2.07	0.076	517.4	8.70	2.47	0.776	8.70	2.47	0.776			
2.050	130.5	37.68	0.80	1354.9	21.73	4.80	0.422	21.73	4.80	0.422	555.1	6.21	0.95	0.835	6.21	0.95	0.835			
2.100	132.3	36.34	0.82	2134.9	20.23	-15.09	0.223	20.23	-15.09	0.223	710.0	7.90	-3.45	0.783	7.9	-3.45	0.783			
2.150	134.1	35.06	0.64	1029.9	32.75	2.07	0.066	32.75	2.07	0.066	488.1	8.60	2.85	0.755	8.6	.85	0.755			
2.200	135.8	33.81	0.70	1345.9	19.57	5.08	0.421	19.57	5.08	0.421	553.3	6.07	0.63	0.820	6.0	.63	0.820			
2.250	137.5	32.59	0.84	2053.6	26.60	-11.95	0.184	26.60	-11.95	0.184	699.4	8.26	-3.19	0.747	8.26	19	0.747			
2.300	139.1	31.29	0.56	806.9	29.79	2.78	0.048	29.79	2.78	0.048	442.1	8.17	4.17	0.739	8.17	4.17	0.739			
2.350	140.6	30.04	0.83	1776.6	16.56	-4.58	0.449	16.56	-4.58	0.449	642.2	6.07	-1.73	0.798	6.07	-1.73	0.798			
2.400	142.1	28.85	0.82	1746.0	25.99	-4.76	0.099	25.99	-4.76	0.099	635.9	9.48	-0.80	0.671	9.48	-0.80	0.671			
2.450	143.5	27.44	0.88	1009.6	17.70	18.64	0.355	17.70	18.64	0.355	502.5	6.15	2.47	0.776	6.15	2.47	0.776			
2.500	144.8	26.23	0.94	2186.3	21.81	-8.93	0.168	21.81	-8.93	0.168	726.8	9.17	-3.18	0.651	9.17	-3.18	0.651			
2.550	146.1	24.79	0.94	863.6	19.81	29.64	0.200	19.81	29.64	0.200	453.8	6.82	4.16	0.725	6.82	4.16	0.725			
2.600	147.3	23.56	0.95	2339.2	18.12	-12.32	0.231	18.12	-12.32	0.231	758.3	9.05	-3.87	0.616	9.05	-3.87	0.616			
2.650	148.5	22.13	0.64	829.6	15.46	30.41	0.301	15.46	30.41	0.301	446.7	6.92	4.55	0.687	6.92	4.55	0.687			
2.700	149.6	20.86	0.66	2349.7	15.76	-12.45	0.245	15.76	-12.45	0.245	760.5	9.50	-3.65	0.544	9.50	-3.65	0.544			
2.750	150.5	19.49	0.86	985.9	5.31	21.25	0.728	5.31	21.25	0.728	480.7	6.34	3.97	0.674	6.34	3.97	0.674			
2.800	151.5	18.17	0.65	2253.2	14.29	-10.56	0.214	14.29	-10.56	0.214	740.6	10.42	-2.65	0.426	10.42	-2.65	0.426			
2.850	152.4	16.83	0.80	1236.0	0.79	8.22	0.953	0.79	8.22	0.953	530.6	5.47	2.12	0.674	5.47	2.12	0.674			
2.900	153.2	15.58	0.94	2012.7	13.34	-5.11	0.144	13.34	-5.11	0.144	690.9	11.48	-0.45	0.262	11.48	-0.45	0.262			
2.950	153.9	14.24	0.77	2141.0	0.0	0.0	1.000	0.0	0.0	1.000	717.4	5.61	-2.86	0.606	5.61	-2.86	0.606			
3.000	154.6	13.02	0.76	1434.7	12.03	-2.53	0.077	12.03	-2.53	0.077	571.6	11.24	3.39	0.136	11.24	3.39	0.136			
3.050	155.2	11.70	0.77	2672.0	0.0	0.0	1.000	0.0	0.0	1.000	827.0	8.06	-4.50	0.310	8.06	-4.50	0.310			

3.100	155.8	10.45	0.85	979.7	7.94	19.63	0.241	7.94	19.63	0.241	477.7	9.44	3.77	0.006	9.44	3.77	0.006
3.150	156.2	9.16	0.77	2193.2	0.0	0.0	1.000	0.0	0.0	1.000	719.9	7.57	-0.69	0.175	7.57	-0.69	0.175
3.200	156.7	7.97	0.73	1992.6	0.0	0.0	1.000	0.0	0.0	1.000	596.0	7.24	-0.02	0.091	7.24	-0.02	0.091
3.250	157.0	6.85	0.50	881.5	6.51	-0.06	0.046	6.51	-0.06	0.046	467.5	6.42	-0.24	0.059	6.42	-0.24	0.059
3.300	157.4	6.22	0.23	385.6	6.12	-0.06	0.018	6.12	-0.06	0.018	231.4	6.06	-0.04	0.025	6.06	-0.04	0.025
3.350	157.7	6.91	0.12	174.1	5.97	1.08	0.010	5.97	1.08	0.010	104.4	5.93	-0.22	0.009	5.93	-0.22	0.009
3.400	158.0	5.27	0.81	1632.5	4.65	-1.61	0.121	4.65	-1.61	0.121	512.5	4.93	-0.86	0.061	4.93	-0.86	0.061
3.450	158.2	4.02	0.78	2568.0	0.0	0.0	1.000	0.0	0.0	1.000	805.6	3.64	-0.78	0.092	3.64	-0.78	0.092
3.500	158.4	2.73	0.81	2918.4	0.0	0.0	1.000	0.0	0.0	1.000	877.9	2.42	-0.75	0.115	2.42	-0.75	0.115
3.550	158.5	1.42	0.80	2945.6	0.0	0.0	1.000	0.0	0.0	1.000	883.5	0.87	-2.52	0.394	0.87	-2.52	0.394

[PX 127, p 3]

[PX 127, p 3]

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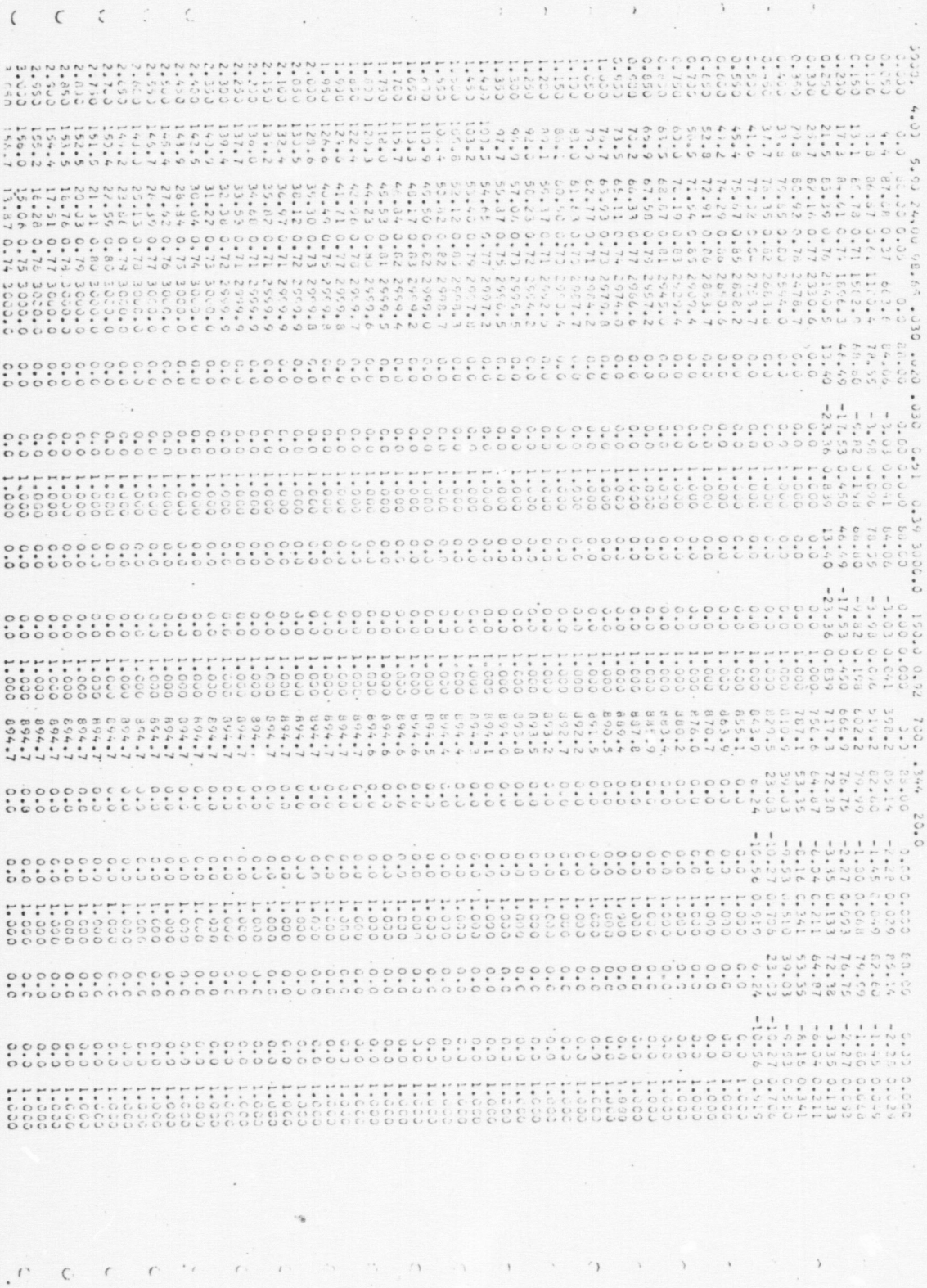

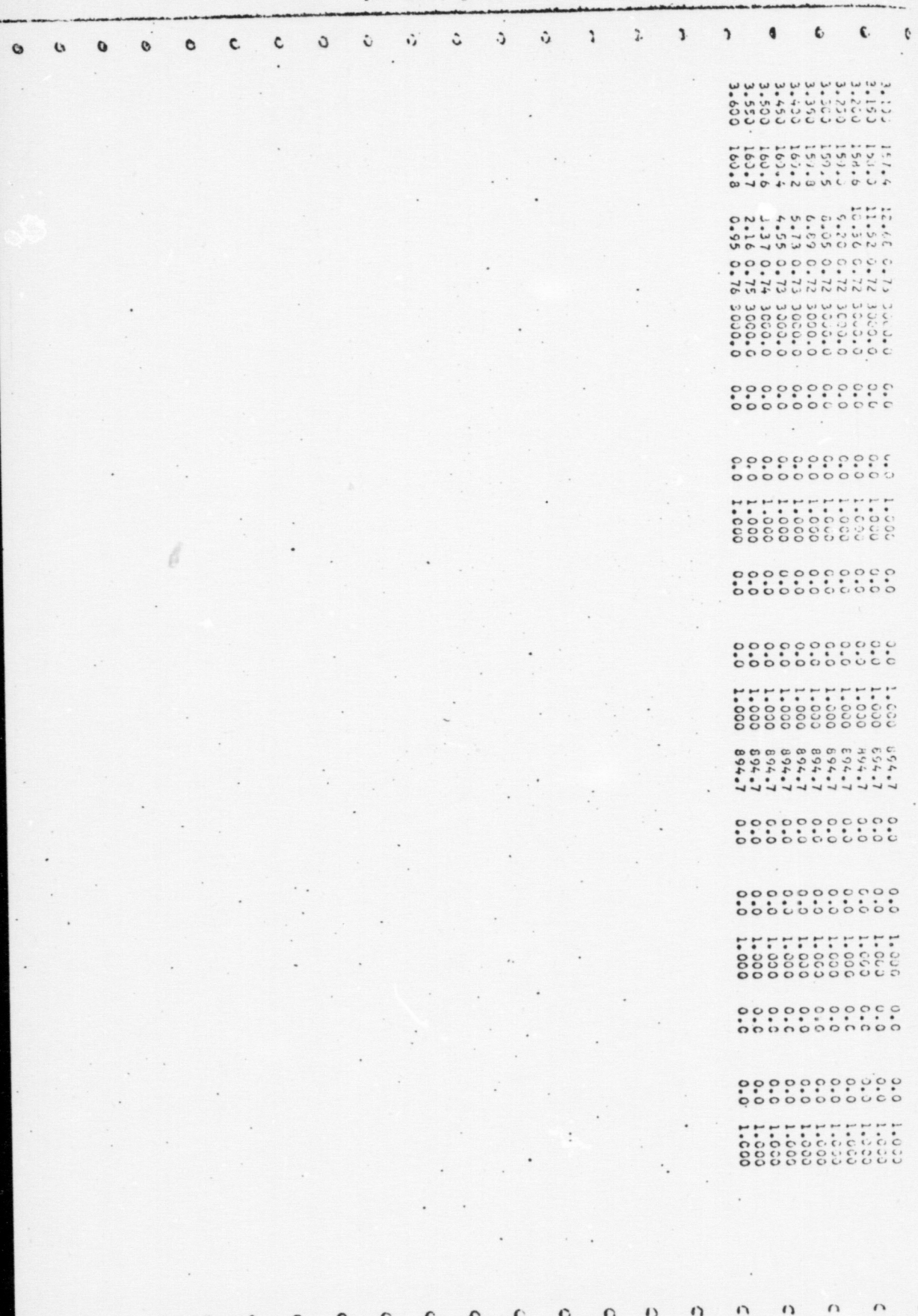

[PX 127, p 6]

[PX 127, p 6]

E-644

3000. 4.0 5.9 24.0 98.6 .030 .020 .030 0.51 0.39 250.0 150.0 0.92 700. .344 20.0

0.000	0.0	36.67	0.01	0.0	36.67	0.00	0.000	36.67	0.00	0.000	0.0	36.67	0.00	0.000	36.67	0.00	0.000		
0.050	1.8	36.36	0.37	663.6	34.97	-1.29	0.038	34.97	-1.29	0.038	398.2	35.32	-1.07	0.029	35.32	-1.07	0.029		
0.100	3.6	35.55	0.61	1100.4	32.64	-1.62	0.082	32.64	-1.62	0.082	519.2	34.00	-0.59	0.044	34.00	-0.89	0.044		
0.150	5.4	34.43	0.77	1582.9	29.31	-3.29	0.143	29.31	-3.29	0.148	602.2	32.37	-1.13	0.060	32.37	-1.13	0.060		
0.200	7.1	33.18	0.77	1896.3	16.07	-13.63	0.515	16.07	-13.63	0.515	666.9	30.42	-1.30	0.084	30.42	-1.30	0.084		
0.250	8.7	31.97	0.75	2140.5	0.0	0.0	1.000	0.0	0.0	1.000	717.3	28.11	-1.70	0.122	28.11	-1.70	0.122		
0.300	10.3	30.75	0.76	2330.6	0.0	0.0	1.000	0.0	0.0	1.000	756.6	23.52	-4.47	0.237	23.52	-4.47	0.237		
0.350	11.8	29.53	0.76	2478.7	0.0	0.0	1.000	0.0	0.0	1.000	787.1	13.73	-7.65	0.536	13.73	-7.65	0.536		
0.400	13.2	28.30	0.77	1267.2	0.93	9.08	0.967	0.93	9.08	0.967	537.1	2.19	-2.32	0.923	2.19	-2.32	0.923		
0.450	14.6	27.30	0.28	239.3	27.03	0.02	0.009	27.03	0.02	0.009	143.6	8.25	10.44	0.698	8.25	10.44	0.698		
0.500	15.9	26.27	0.97	2142.5	22.98	-3.59	0.125	22.98	-3.59	0.125	717.7	10.63	-4.56	0.595	10.63	-4.56	0.595		
0.550	17.2	24.77	0.59	987.4	23.71	1.02	0.043	23.71	1.02	0.043	479.3	4.82	1.88	0.805	4.82	1.88	0.805		
0.600	18.4	23.90	0.84	1690.0	22.07	-2.93	0.078	22.07	-2.93	0.078	624.3	12.63	0.73	0.471	12.63	0.73	0.471		
0.650	19.6	22.36	0.88	2648.6	3.94	-27.12	0.824	3.94	-27.12	0.824	822.2	8.36	-4.99	0.625	8.36	-4.99	0.625		
0.700	20.7	20.98	0.93	809.9	11.00	28.68	0.476	11.00	28.68	0.476	442.7	8.40	6.55	0.599	8.40	6.55	0.599		
0.750	21.7	19.50	0.92	2471.4	9.65	-21.10	0.506	9.65	-21.10	0.506	785.6	11.18	-2.30	0.425	11.18	-2.30	0.425		
0.800	22.6	18.18	0.79	1811.5	0.0	0.0	1.000	0.0	0.0	1.000	649.4	5.66	0.19	0.688	5.66	0.19	0.688		
0.850	23.5	16.81	0.89	2016.8	10.69	-10.12	0.365	10.69	-10.12	0.365	691.8	11.43	0.38	0.319	11.43	0.38	0.319		
0.900	24.3	15.54	0.75	2594.6	0.0	0.0	1.000	0.0	0.0	1.000	811.0	6.52	-4.76	0.580	6.52	-4.76	0.580		
0.950	25.1	14.30	0.87	1169.4	12.37	13.12	0.135	12.37	13.12	0.135	516.9	10.27	4.76	0.281	10.27	4.76	0.281		
1.000	25.7	13.02	0.73	2636.2	0.0	0.0	1.000	0.0	0.0	1.000	819.6	9.36	-4.35	0.281	9.36	-4.35	0.281		
1.050	26.4	11.86	0.74	949.3	1.57	10.87	0.868	1.57	10.87	0.868	471.5	6.36	4.71	0.463	6.36	4.71	0.463		
1.100	26.9	10.65	0.75	2281.1	1.17	-27.46	0.890	1.17	-27.46	0.890	746.3	9.18	-1.88	0.138	9.18	-1.88	0.138		
1.150	27.4	9.47	0.75	1127.6	0.45	5.26	0.952	0.45	5.26	0.952	508.3	7.49	4.88	0.210	7.49	4.88	0.210		
1.200	27.9	8.29	0.73	1771.8	0.0	0.0	1.000	0.0	0.0	1.000	641.2	7.47	-0.61	0.101	7.47	-0.61	0.101		
1.250	28.3	7.14	0.73	1189.4	1.67	7.28	0.765	1.67	7.28	0.765	521.0	6.66	-0.62	0.069	6.66	-0.62	0.069		
1.300	28.6	6.32	0.25	417.5	6.20	-0.08	0.019	6.20	-0.08	0.019	250.5	6.16	-0.17	0.028	6.16	-0.17	0.028		
1.350	28.9	5.99	0.13	184.1	5.93	1.23	0.010	5.93	1.23	0.010	110.5	5.91	-0.02	0.011	5.91	-0.02	0.011		
1.400	29.2	5.53	0.65	1254.7	5.17	-0.97	0.067	5.17	-0.97	0.067	534.5	5.22	-0.74	0.052	5.22	-0.74	0.052		
1.450	29.4	4.22	0.81	2433.2	0.0	0.0	1.000	0.0	0.0	1.000	777.7	3.85	-0.81	0.087	3.85	-0.81	0.087		
1.500	29.6	2.83	0.85	2887.1	0.0	0.0	1.000	0.0	0.0	1.000	871.4	2.56	-0.78	0.112	2.56	-0.78	0.112		
1.550	29.7	1.51	0.85	2977.5	0.0	0.0	1.000	0.0	0.0	1.000	890.1	1.24	-1.27	0.184	1.24	-1.27	0.184		

PLAINTIFF'S EXHIBIT 128
(FIRST THREE STOPS)

TT 128

Simulation of Perma Anti-Skid Device

Threshold .92g

Pressure switch settings:	Opens	Closes
in footpounds	150	250
in PSI (approximately)	115	159

Gear Ratio 12:1

Surface Coefficient of Friction	Speed	With (Distance in Feet)	Without (Distance in Feet)
.75	60	158.3	160.8
	25	31.3	29.3
.7	60	167.1	171.2
	40	78.6	77.9
	25	32.9	31.2
.5	60	172.8	188.2
	25	30.8	29.1
.2	35	172.1	195.6
	25	89.5	101.4
	15	32.6	36.8
.15	25	120.0	134.6
	20	77.0	86.8
	15	44.9	49.1

[PX 128, p 2]

0.000	0.0	88.00	0.00	0.0	88.00	0.00	0.000	88.00	0.00	0.000	0.0	88.00	0.00	0.000	88.00	0.00	0.000					
0.050	4.4	87.48	0.37	663.6	84.04	43.03	0.041	84.04	-3.03	0.041	331.2	85.14	-2.25	0.029	85.14	-2.23	0.029					
0.100	8.8	86.87	0.61	1160.4	78.55	-3.98	0.096	78.55	-3.98	0.096	519.2	82.60	-1.45	0.049	82.60	-1.45	0.049					
0.150	13.1	86.78	0.71	1532.9	68.80	-9.82	0.190	68.80	-9.82	0.190	602.2	79.99	-1.83	0.063	79.99	-1.83	0.063					
0.200	17.3	86.61	0.74	1666.3	46.49	-17.53	0.456	46.49	-17.53	0.456	644.9	76.75	-2.27	0.093	76.75	-2.27	0.093					
0.250	21.5	83.39	0.76	2140.5	13.40	-23.36	0.889	13.40	-23.36	0.889	717.3	72.38	-3.35	0.133	72.38	-3.35	0.133					
0.300	25.7	82.16	0.77	2330.6	0.0	0.0	1.000	0.0	0.0	1.000	737.1	53.35	-8.16	0.341	53.35	-8.16	0.341					
0.350	29.4	80.92	0.78	2473.7	0.0	0.0	1.000	0.0	0.0	1.000	810.9	39.03	-9.53	0.510	39.03	-9.53	0.510					
0.400	33.2	79.65	0.80	2594.0	0.0	0.0	1.000	0.0	0.0	1.000	829.5	23.03	-10.27	0.706	23.03	-10.27	0.736					
0.450	37.7	78.35	0.82	2683.0	0.0	0.0	1.000	0.0	0.0	1.000	829.5	23.03	-2.48	0.880	9.28	-2.48	0.880					
0.500	41.6	77.02	0.84	1396.8	0.65	7.62	0.992	0.65	7.62	0.992	553.8	9.28	9.71	0.798	15.25	9.71	0.798					
0.550	45.4	75.63	0.86	269.2	48.73	44.13	0.356	48.73	44.13	0.356	159.1	15.25	9.71	0.798	15.10	-5.32	0.797					
0.600	49.2	74.23	0.92	2095.1	64.08	-7.30	0.138	64.08	-7.30	0.138	707.9	15.10	-5.32	0.797	14.81	2.67	0.797					
0.650	52.8	73.05	0.94	902.6	70.29	-2.55	0.038	70.29	-2.55	0.038	461.8	14.81	2.67	0.797	15.65	-1.03	0.782					
0.700	56.5	71.80	0.82	1742.2	65.23	-6.33	0.093	65.23	-6.33	0.093	666.1	15.65	-1.03	0.782	15.62	-0.73	0.778					
0.750	60.0	70.52	0.87	1825.6	62.55	-6.08	0.114	62.55	-6.08	0.114	691.9	15.62	-0.73	0.778	15.66	0.05	0.773					
0.800	63.5	69.11	0.88	1770.1	57.47	-3.75	0.169	57.47	-3.75	0.169	640.9	15.66	0.05	0.773	15.48	1.27	0.771					
0.850	66.9	67.72	0.85	1579.9	47.54	-0.98	0.298	47.54	-0.98	0.298	611.6	15.48	1.27	0.771	15.86	-0.17	0.761					
0.900	70.3	66.38	0.81	1763.8	36.33	-9.73	0.453	36.33	-9.73	0.453	645.8	15.86	-0.17	0.761	15.34	-1.40	0.764					
0.950	73.6	65.11	0.77	1929.0	18.77	-16.50	0.712	18.77	-16.50	0.712	673.7	15.34	-1.40	0.764	15.28	-0.92	0.761					
1.000	76.8	63.91	0.73	1786.1	2.26	-14.91	0.965	2.26	-14.91	0.965	644.6	15.28	-0.92	0.761	14.91	0.22	0.762					
1.050	80.0	62.75	0.71	1551.4	0.0	0.0	1.000	0.0	0.0	1.000	595.7	14.91	0.22	0.762	15.26	1.00	0.752					
1.100	83.1	61.60	0.71	1365.4	0.0	0.0	1.000	0.0	0.0	1.000	563.5	15.26	1.00	0.752	15.34	1.72	0.746					
1.150	86.1	60.46	0.71	1263.8	0.0	0.0	1.000	0.0	0.0	1.000	536.4	15.34	1.72	0.746	15.51	-1.04	0.739					
1.200	89.1	59.31	0.72	1733.2	0.0	0.0	1.000	0.0	0.0	1.000	633.3	15.51	-1.04	0.739	15.67	-0.62	0.731					
1.250	92.1	58.15	0.73	1671.8	0.0	0.0	1.000	0.0	0.0	1.000	620.6	15.67	-0.62	0.731	14.77	-1.09	0.741					
1.300	94.9	56.76	0.75	1755.2	0.0	0.0	1.000	0.0	0.0	1.000	637.8	14.77	-1.09	0.741	15.43	0.27	0.723					
1.350	97.8	55.74	0.77	1556.9	0.0	0.0	1.000	0.0	0.0	1.000	593.1	15.43	0.27	0.723	15.14	1.51	0.732					
1.400	100.5	54.63	0.79	1030.0	0.38	3.46	0.993	0.38	3.46	0.993	550.0	15.14	1.51	0.732	15.62	0.56	0.707					
1.450	103.2	53.20	0.81	1493.5	0.98	0.33	0.982	0.98	0.33	0.982	583.8	15.62	0.56	0.707	15.44	-1.20	0.703					
1.500	105.8	51.10	0.82	1782.6	0.75	-6.71	0.985	0.75	-6.71	0.985	643.5	15.44	-1.20	0.703	15.57	-0.65	0.692					
1.550	108.4	50.56	0.84	1714.7	4.39	-3.10	0.913	4.39	-3.10	0.913	629.4	15.57	-0.65	0.692	14.63	-0.62	0.703					
1.600	110.9	49.20	0.84	1649.7	2.58	-0.93	0.946	2.58	-0.93	0.946	616.0	14.63	-0.62	0.703	15.20	0.24	0.682					
1.650	113.5	47.32	0.87	1493.1	10.67	5.52	0.777	10.67	5.52	0.777	583.7	15.20	0.24	0.682	14.82	1.75	0.681					
1.700	115.7	46.41	0.88	1219.9	17.63	14.74	0.620	17.63	14.74	0.620	527.3	14.82	1.75	0.681	15.47	-0.03	0.666					
1.750	117.9	44.95	0.93	1487.3	34.69	10.61	0.228	34.69	10.61	0.228	582.5	15.47	-0.03	0.666	15.64	1.59	0.644					
1.800	120.2	43.62	0.65	1219.8	41.21	-2.86	0.056	41.21	-2.86	0.056	527.2	15.64	1.59	0.644	15.17	-2.03	0.642					
1.850	122.3	42.36	0.88	1871.5	37.47	-4.36	0.116	37.47	-4.36	0.116	651.8	15.17	-2.03	0.642	15.51	-0.71	0.622					
1.900	124.4	41.09	0.84	1695.0	36.80	-2.58	0.105	36.80	-2.58	0.105	625.4	15.51	-0.71	0.622	14.92	0.08	0.624					
1.950	126.4	39.74	0.88	1594.4	34.34	3.45	0.136	34.34	3.45	0.136	630.5	14.92	0.08	0.624	15.34	1.17	0.600					
2.000	128.4	38.41	0.82	1434.8	34.21	3.57	0.110	34.21	3.57	0.110	571.7	15.34	1.17	0.600	15.61	0.46	0.579					
2.050	130.3	37.07	0.83	1575.3	32.78	-0.28	0.116	32.78	-0.28	0.116	600.8	15.61	0.46	0.579	15.73	0.00	0.560					
2.100	132.1	35.72	0.81	1648.2	31.70	-3.24	0.113	31.70	-3.24	0.113	610.9	15.73	0.00	0.560	15.23	-1.65	0.557					
2.150	133.8	34.55	0.85	1903.4	28.37	-7.80	0.174	28.37	-7.80	0.174	663.4	15.23	-1.65	0.557	15.46	-0.42	0.532					
2.200	135.5	33.32	0.89	1695.7	28.38	-1.25	0.1	28.38	-1.25	0.140	624.5	15.46	-0.42	0.532	14.95	0.74	0.528					
2.250	137.1	31.44	0.86	1474.5	26.14	5.62	0.7	26.14	5.62	0.174	579.9	14.95	0.74	0.528	15.47	1.35	0.490					
2.300	138.7	30.33	0.77	1591.7	27.67	0.78	0.687	27.67	0.78	0.687	562.9	15.47	1.35	0.490	15.61	-0.25	0.482					
2.350	140.2	29.60	0.82	1685.8	26.06	-3.16	0.101	26.06	-3.16	0.101	633.9	15.74	-0.39	0.431	15.74	-0.39	0.431					
2.400	141.6	27.46	0.84	1736.2	24.84	-3.31	0.101	24.84	-3.31	0.101	640.9	15.23	-0.03	0.402	15.00	-0.83	0.402					
2.450	142.9	26.26	0.83	1613.7	22.62	0.91	0.158	22.62	0.91	0.158	600.5	15.16	0.61	0.391	15.16	0.61	0.391					
2.500	144.2	24.95	0.86	1593.7	22.44	1.96	0.097	22.44	1.96	0.097	634.5	15.36	0.53	0.329	15.86	0.53	0.325					
2.550	145.4	23.48	0.85	1669.9	21.35	-1.12	0.090	21.35	-1.12	0.090	643.2	15.36	0.01	0.286	15.75	0.01	0.286					
2.600	146.5	22.04	0.83	1784.8	19.95	-2.61	0.094	19.95	-2.61	0.094	663.9	15.75	0.01	0.286	15.92	-0.54	0.227					
2.650	147.6	20.80	0.94	1915.9	16.30	-1.92	0.111	15.30	-1.92	0.111	671.0	15.92	-0.54	0.227	15.82	-0.38	0.197					
2.700	148.6	19.08	0.88	1842.9	15.61	2.46	0.130	15.61	2.46	0.130	651.0	15.82	-0.38	0.197	15.49	0.41	0.182					
2.750	149.5	17.60	0.86	1643.5	16.02	0.29	0.093	16.02	0.29	0.090	611.0	15.49	0.41	0.182	14.85	-0.10	0.037					
2.800	150.4	16.26	0.66	1257.4	15.30	-0.64	0.059	15.30	-0.64	0.059	533.1	14.85	-0.10	0.037	14.27	-0.32	0.038					
2.850	151.1	15.18	0.44	700.1	14.69	-0.59	0.036	14.69	-0.59	0.036	435.5	14.27	-0.32	0.038	13.52	-0.61	0.033					
2.900	151.9	14.31	0.56	796.8	13.84	-0.97	0.035	13.84	-0.97	0.035	440.0	13.52	-0.61	0.033	13.02	-0.88	0.033					
2.950	152.6	13.40	0.36	634.4	13.24	-0.79	0.028	13.24	-0.79	0.028	390.7	13.02	-0.88	0.033	12.71	-0.53	0.023					
3.000	153.2	13.06	0.25	433.7	12.84	-0.54	0.020	12.84	-0.54	0.020	260.2	12.71	-0.53	0.023	12.49	-0.25	0.012					
3.050	153.9	12.68	0.15	254.0	12.56	-0.29	0.012	12.56	-0.29	0.012	152.4	12.49	-0.25	0.012								

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3.100	154.5	12.43	0.03	137.8	12.36	-0.06	0.007	12.36	-0.06	0.007	[illegible]7	12.33	-0.03	0.006	12.33	-0.03	0.006
3.150	155.1	11.85	0.75	1435.1	10.42	-2.88	0.121	10.42	-2.88	0.121	571.7	11.32	-0.87	0.044	11.32	-0.87	0.044
3.200	155.7	10.74	0.68	2443.6	0.0	0.0	1.000	0.0	0.0	1.000	779.9	10.00	-0.83	0.069	10.00	-0.83	0.069
3.250	156.2	9.61	0.72	2894.9	0.0	0.0	1.000	0.0	0.0	1.000	873.0	8.71	-0.79	0.093	8.71	-0.79	0.093
3.300	156.6	8.44	0.73	2980.1	0.0	0.0	1.000	0.0	0.0	1.000	890.6	7.41	-0.88	0.123	7.41	-0.88	0.123
3.350	157.0	7.28	0.69	2215.5	0.0	0.0	1.000	0.0	0.0	1.000	732.8	6.53	-0.54	0.104	6.53	-0.54	0.104
3.400	157.4	6.15	0.71	2260.3	0.0	0.0	1.000	0.0	0.0	1.000	742.0	4.53	-1.70	0.266	4.53	-1.70	0.266
3.450	157.7	5.04	0.70	1566.5	0.0	0.0	1.000	0.0	0.0	1.000	598.8	4.58	-0.89	0.100	4.58	-0.89	0.100
3.500	157.9	3.88	0.74	1245.4	0.24	4.85	0.938	0.24	4.85	0.938	532.6	1.92	0.44	0.512	1.92	0.44	0.512
3.550	158.0	3.25	0.05	235.2	3.43	-6.74	0.0	3.43	-6.74	0.0	141.1	3.26	-0.40	0.016	3.26	-0.40	0.016
3.600	158.2	2.87	0.46	1097.0	2.76	-9.62	0.033	2.75	-9.62	0.033	501.9	2.71	-0.92	0.065	2.71	-0.92	0.065
3.650	158.3	1.92	0.86	2402.2	0.0	0.0	1.000	0.0	0.0	1.000	771.3	1.12	-2.09	0.273	1.12	-2.09	0.273

[PX 128, p 4]

3000.0	8.00	11.84	12.00	78.65	.000	.020	.000	0.51	0.36	3000.0	150.0	0.92	700.	.344	20.0							
0.000	0.0	88.00	0.00		0.0	88.00		0.00	0.000	88.00	0.00	0.000		0.0	88.00		0.00	0.000	88.00		0.00	0.000
0.050	4.4	87.06	0.37	663.6	88.00		-3.03	0.041	84.06		-3.03	0.041	393.2	85.14		-2.28	0.029	85.14		-2.28	0.029	
0.100	8.8	84.87	0.61	1170.4	78.55		-5.98	0.096	78.55		-5.98	0.096	519.2	82.60		-1.45	0.049	82.60		-1.45	0.049	
0.150	13.1	82.79	0.71	1582.9	68.60		-9.82	0.198	68.60		-9.82	0.198	602.2	79.49		-1.80	0.068	79.49		-1.80	0.068	
0.200	17.3	84.61	0.74	1866.3	48.49		-17.53	0.450	48.49		-17.53	0.450	666.9	76.75		-2.27	0.093	76.75		-2.27	0.093	
0.250	21.5	83.39	0.74	2140.5	18.40		-23.36	0.839	18.40		-23.36	0.839	717.3	72.38		-3.35	0.133	72.38		-3.35	0.133	
0.300	25.7	82.16	0.77	2350.6	0.0		0.0	1.000	0.0		0.0	1.000	756.6	64.87		-6.04	0.211	64.87		-6.04	0.211	
0.350	29.8	80.92	0.78	2478.7	0.0		0.0	1.000	0.0		0.0	1.000	787.1	53.35		-8.16	0.341	53.35		-8.16	0.341	
0.400	33.8	79.65	0.80	2594.0	0.0		0.0	1.000	0.0		0.0	1.000	810.9	39.03		-9.53	0.510	39.03		-9.53	0.510	
0.450	37.7	78.35	0.82	2683.8	0.0		0.0	1.000	0.0		0.0	1.000	829.5	23.03		-10.27	0.706	23.03		-10.27	0.706	
0.500	41.6	77.02	0.84	2753.7	0.0		0.0	1.000	0.0		0.0	1.000	843.9	6.24		-10.56	0.919	6.24		-10.56	0.919	
0.550	45.4	75.67	0.85	2808.2	0.0		0.0	1.000	0.0		0.0	1.000	855.1	0.0		0.0	1.000	0.0		0.0	1.000	
0.600	49.2	74.29	0.86	2850.6	0.0		0.0	1.000	0.0		0.0	1.000	863.9	0.0		0.0	1.000	0.0		0.0	1.000	
0.650	52.8	72.91	0.88	2883.7	0.0		0.0	1.000	0.0		0.0	1.000	870.7	0.0		0.0	1.000	0.0		0.0	1.000	
0.700	56.5	71.54	0.89	2909.4	0.0		0.0	1.000	0.0		0.0	1.000	876.0	0.0		0.0	1.000	0.0		0.0	1.000	
0.750	60.0	70.19	0.83	2929.4	0.0		0.0	1.000	0.0		0.0	1.000	880.2	0.0		0.0	1.000	0.0		0.0	1.000	
0.800	63.5	68.87	0.81	2945.0	0.0		0.0	1.000	0.0		0.0	1.000	883.4	0.0		0.0	1.000	0.0		0.0	1.000	
0.850	66.9	67.58	0.79	2957.2	0.0		0.0	1.000	0.0		0.0	1.000	885.9	0.0		0.0	1.000	0.0		0.0	1.000	
0.900	70.2	66.33	0.77	2966.6	0.0		0.0	1.000	0.0		0.0	1.000	887.8	0.0		0.0	1.000	0.0		0.0	1.000	
0.950	73.5	65.11	0.74	2974.0	0.0		0.0	1.000	0.0		0.0	1.000	889.4	0.0		0.0	1.000	0.0		0.0	1.000	
1.000	76.7	63.93	0.73	2979.8	0.0		0.0	1.000	0.0		0.0	1.000	890.5	0.0		0.0	1.000	0.0		0.0	1.000	
1.050	79.9	62.77	0.71	2984.2	0.0		0.0	1.000	0.0		0.0	1.000	891.5	0.0		0.0	1.000	0.0		0.0	1.000	
1.100	83.0	61.63	0.70	2987.7	0.0		0.0	1.000	0.0		0.0	1.000	892.2	0.0		0.0	1.000	0.0		0.0	1.000	
1.150	86.1	60.50	0.70	2990.4	0.0		0.0	1.000	0.0		0.0	1.000	892.7	0.0		0.0	1.000	0.0		0.0	1.000	
1.200	89.1	59.37	0.71	2992.5	0.0		0.0	1.000	0.0		0.0	1.000	893.2	0.0		0.0	1.000	0.0		0.0	1.000	
1.250	92.0	58.23	0.72	2994.2	0.0		0.0	1.000	0.0		0.0	1.000	893.5	0.0		0.0	1.000	0.0		0.0	1.000	
1.300	94.9	57.06	0.73	2995.5	0.0		0.0	1.000	0.0		0.0	1.000	893.8	0.0		0.0	1.000	0.0		0.0	1.000	
1.350	97.7	55.87	0.75	2996.5	0.0		0.0	1.000	0.0		0.0	1.000	894.0	0.0		0.0	1.000	0.0		0.0	1.000	
1.400	100.5	54.65	0.77	2997.2	0.0		0.0	1.000	0.0		0.0	1.000	894.1	0.0		0.0	1.000	0.0		0.0	1.000	
1.450	103.2	53.40	0.79	2997.8	0.0		0.0	1.000	0.0		0.0	1.000	894.3	0.0		0.0	1.000	0.0		0.0	1.000	
1.500	105.8	52.12	0.80	2998.2	0.0		0.0	1.000	0.0		0.0	1.000	894.4	0.0		0.0	1.000	0.0		0.0	1.000	
1.550	109.4	50.82	0.82	2998.7	0.0		0.0	1.000	0.0		0.0	1.000	894.4	0.0		0.0	1.000	0.0		0.0	1.000	
1.600	110.9	49.50	0.82	2999.0	0.0		0.0	1.000	0.0		0.0	1.000	894.5	0.0		0.0	1.000	0.0		0.0	1.000	
1.650	113.3	48.17	0.83	2999.2	0.0		0.0	1.000	0.0		0.0	1.000	894.6	0.0		0.0	1.000	0.0		0.0	1.000	
1.700	115.7	46.84	0.82	2999.4	0.0		0.0	1.000	0.0		0.0	1.000	894.6	0.0		0.0	1.000	0.0		0.0	1.000	
1.750	118.0	45.53	0.81	2999.5	0.0		0.0	1.000	0.0		0.0	1.000	894.6	0.0		0.0	1.000	0.0		0.0	1.000	
1.800	120.3	44.23	0.80	2999.6	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
1.850	122.4	42.96	0.78	2999.7	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
1.900	124.6	41.71	0.77	2999.8	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
1.950	126.6	40.49	0.75	2999.8	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.000	128.6	39.30	0.73	2999.8	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.050	130.5	38.12	0.72	2999.9	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.100	132.4	36.97	0.71	2999.9	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.150	134.2	35.82	0.71	2999.9	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.200	136.0	34.68	0.71	2999.9	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.250	137.7	33.53	0.71	2999.9	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.300	139.4	32.38	0.72	2999.9	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.350	140.9	31.22	0.73	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.400	142.5	30.04	0.74	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.450	143.9	28.84	0.75	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.500	145.4	27.62	0.75	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.550	146.7	26.39	0.77	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.600	148.0	25.13	0.78	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.650	149.2	23.84	0.79	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.700	150.4	22.53	0.80	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.750	151.5	21.21	0.80	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.800	152.5	20.00	0.79	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.850	153.5	18.78	0.78	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.900	154.4	17.51	0.77	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
2.950	155.2	16.28	0.76	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
3.000	155.9	15.08	0.75	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	
3.050	156.7	13.87	0.74	3000.0	0.0		0.0	1.000	0.0		0.0	1.000	894.7	0.0		0.0	1.000	0.0		0.0	1.000	

[PX 128, p 4]

[PX 128, p 6]

0.000	0.0	36.67	0.01	0.0	36.67	0.00	0.000	36.67	0.00	0.000	0.0	36.67	0.00	0.000	36.67	0.00	0.000	
0.050	1.8	36.34	0.27	663.6	34.97	-1.29	0.038	34.97	-1.29	0.038	333.2	35.32	-1.07	0.029	35.32	-1.07	0.029	
0.100	3.6	35.95	0.41	1180.4	33.64	-1.62	0.063	33.64	-1.62	0.063	519.2	34.00	-0.89	0.044	34.00	-0.89	0.044	
0.150	5.4	34.43	0.77	1542.9	29.31	-3.29	0.148	29.31	-3.29	0.148	602.2	32.37	-1.13	0.060	32.37	-1.13	0.060	
0.200	7.1	33.18	0.77	1866.3	16.07	-13.63	0.915	16.07	-13.63	0.915	666.9	30.42	-1.30	0.084	30.42	-1.30	0.084	
0.250	8.7	31.97	0.75	2140.5	0.0	0.0	1.000	0.0	0.0	1.000	717.3	28.11	-1.70	0.122	28.11	-1.70	0.122	
0.300	10.3	30.75	0.76	2380.6	0.0	0.0	1.000	0.0	0.0	1.000	756.6	23.52	-4.47	0.237	23.52	-4.47	0.237	
0.350	11.8	29.53	0.76	2593.4	0.0	0.0	1.000	0.0	0.0	1.000	790.6	13.91	-6.29	0.530	13.91	-6.29	0.530	
0.400	13.2	28.23	0.61	447.9	26.73	19.25	0.052	26.73	19.25	0.052	268.8	14.25	6.03	0.497	14.25	6.83	0.497	
0.450	14.6	27.21	0.91	1929.8	24.24	-1.56	0.108	24.24	-1.56	0.108	673.8	15.06	-3.77	0.418	15.06	-3.77	0.418	
0.500	15.9	26.04	0.61	1098.7	24.87	-1.45	0.044	24.87	-1.45	0.044	502.3	15.36	1.90	0.411	15.36	1.90	0.411	
0.550	17.2	24.83	0.68	1793.8	22.66	-1.69	0.087	22.66	-1.69	0.087	645.8	16.08	-0.99	0.352	16.08	-0.99	0.352	
0.600	18.4	23.63	0.61	1777.4	21.29	-0.10	0.092	21.29	-0.10	0.092	642.4	15.97	0.12	0.318	15.97	0.12	0.318	
0.650	19.5	21.96	0.56	1933.4	19.64	-1.69	0.106	19.64	-1.69	0.106	674.6	16.78	0.26	0.234	16.78	0.26	0.234	
0.700	20.6	20.33	1.01	2109.3	16.66	-3.63	0.181	16.66	-3.63	0.181	710.9	16.46	-0.37	0.189	16.46	-0.37	0.189	
0.750	21.6	18.75	0.93	2009.1	10.08	-6.11	0.463	10.08	-6.11	0.463	690.2	15.38	-0.25	0.125	15.38	-0.25	0.125	
0.800	22.5	17.38	0.79	1750.7	0.0	0.0	1.000	0.0	0.0	1.000	636.9	15.63	-0.59	0.099	15.63	-0.59	0.099	
0.850	23.3	16.13	0.75	1492.1	0.16	-1.34	0.990	0.16	-1.34	0.990	583.5	14.78	-0.78	0.082	14.78	-0.78	0.082	
0.900	24.1	14.93	0.60	1110.4	14.05	0.00	0.060	14.05	0.00	0.060	504.7	13.91	-0.51	0.066	13.91	-0.51	0.066	
0.950	24.8	14.23	0.46	813.8	13.65	-0.29	0.042	13.65	-0.29	0.042	448.5	13.45	-0.38	0.053	13.45	-0.38	0.053	
1.000	25.5	13.74	0.40	703.4	13.26	-0.75	0.037	13.26	-0.75	0.037	420.7	13.12	-0.83	0.042	13.12	-0.83	0.042	
1.050	26.2	13.28	0.33	561.9	12.90	-0.40	0.030	12.90	-0.40	0.030	337.1	12.84	-0.40	0.031	12.84	-0.40	0.031	
1.100	26.9	12.95	0.23	394.1	12.68	-0.35	0.022	12.68	-0.35	0.022	236.5	12.68	-0.31	0.019	12.68	-0.31	0.019	
1.150	27.5	12.72	0.15	275.0	12.54	-0.54	0.015	12.54	-0.54	0.015	165.0	12.57	-0.42	0.011	12.57	-0.42	0.011	
1.200	28.1	11.05	0.71	1571.8	9.45	-7.45	0.209	9.45	-7.45	0.209	599.9	11.39	-0.85	0.047	11.39	-0.85	0.047	
1.250	28.7	10.88	0.69	2513.6	0.0	0.0	1.000	0.0	0.0	1.000	794.3	10.09	-0.83	0.072	10.09	-0.83	0.072	
1.300	29.2	9.73	0.75	2904.1	0.0	0.0	1.000	0.0	0.0	1.000	874.9	8.78	-0.81	0.098	8.78	-0.81	0.098	
1.350	29.7	8.54	0.75	2978.8	0.0	0.0	1.000	0.0	0.0	1.000	890.3	7.38	-1.04	0.137	7.38	-1.04	0.137	
1.400	30.1	7.35	0.74	2422.8	0.0	0.0	1.000	0.0	0.0	1.000	775.6	6.45	-0.98	0.126	6.45	-0.98	0.126	
1.450	30.4	6.16	0.71	1416.4	0.0	0.0	1.000	0.0	0.0	1.000	567.9	5.67	-0.26	0.087	5.67	-0.26	0.087	
1.500	30.7	4.98	0.76	2031.4	0.0	0.0	1.000	0.0	0.0	1.000	694.8	3.78	-2.59	0.251	3.78	-2.59	0.251	
1.550	30.9	3.97	0.11	488.8	4.04	-14.00	0.0	4.04	-14.00	0.0	293.3	3.88	-0.18	0.042	3.88	-0.18	0.042	
1.600	31.1	3.72	0.07	340.6	3.92	-9.76	0.0	3.92	-9.76	0.0	204.3	3.67	-0.74	0.022	3.67	-0.74	0.022	
1.650	31.2	2.74	0.68	1974.3	2.41	-0.55	0.118	2.41	-0.55	0.118	683.0	2.46	-1.01	0.108	2.46	-1.01	0.108	
1.700	31.3	1.29	0.65	1773.5	0.0	0.0	1.000	0.0	0.0	1.000	641.6	1.17	-0.79	0.093	1.17	-0.79	0.093	

[PX 128, p 6]

E-650

PLAINTIFF'S EXHIBIT 129
(FIRST THREE STOPS)

Simulation of Perma Anti-Skid Device

Threshold .92g

Pressure Switch Setting:	Opens	Closes
in footpounds	150	250
in psi (approximately)	115	159

Gear Ratio 18:1

Surface Coefficient of Friction	MPH Speed	With Distance in Feet	Without Distance in Feet
.75	60	157.7	160.8
	25	29.8	29.3
.7	60	166.9	171.2
	40	77.5	77.9
	25	31.5	31.2
.5	60	174.1	188.2
	25	29.3	29.1
.2	35	167.4	195.6
	25	83.3	101.4
	15	32.8	36.8
.15	25	122.9	134.6
	20	78.0	86.8
	15	43.6	49.1

[PX 129, p 3]

3.100	154.9	9.42	0.43	741.1	9.10	-0.26	0.036	9.10	-0.26	0.036	428.5	8.87	-0.25	0.057	8.87	-0.25	0.057
3.150	155.4	8.73	0.26	438.6	8.57	-0.19	0.020	8.57	-0.19	0.020	263.1	8.45	-0.13	0.029	8.45	-0.13	0.029
3.200	155.8	8.33	0.14	220.2	8.26	-0.05	0.011	8.26	-0.05	0.011	136.9	8.18	-0.02	0.013	8.18	-0.02	0.013
3.250	156.2	8.13	0.09	151.9	8.10	-0.22	0.007	8.10	-0.22	0.007	91.1	8.04	-0.19	0.007	8.04	-0.19	0.007
3.300	156.6	7.43	0.78	1578.4	6.47	-2.34	0.131	6.47	-2.34	0.131	601.3	7.02	-0.86	0.052	7.02	-0.86	0.052
3.350	157.0	6.24	0.74	2531.8	0.0	0.0	1.000	0.0	0.0	1.000	798.1	5.75	-0.78	0.077	5.75	-0.78	0.077
3.400	157.2	5.03	0.77	2911.6	0.0	0.0	1.000	0.0	0.0	1.000	876.5	4.55	-0.75	0.096	4.55	-0.75	0.096
3.450	157.5	3.79	0.78	2983.3	0.0	0.0	1.000	0.0	0.0	1.000	891.3	3.34	-0.77	0.121	3.34	-0.77	0.121
3.500	157.6	2.55	0.76	2249.0	0.0	0.0	1.000	0.0	0.0	1.000	739.7	1.70	0.99	0.337	1.70	0.99	0.337
3.550	157.7	1.39	0.74	2105.1	0.0	0.0	1.000	0.0	0.0	1.000	710.0	1.26	-0.73	0.111	1.26	-0.73	0.111

[PX 129, p 3]

[PX 129, p 4]

[PX 129, p 4]

E-654

[PX 129, p 5]

3.100	157.4	12.68	0.73	3000.0	0.0	0.0	1.000	0.0	0.0	1.000	894.7	0.0	0.0	1.000	0.0	0.0	1.000
3.150	158.0	11.52	0.72	3000.0	0.0	0.0	1.000	0.0	0.0	1.000	894.7	0.0	0.0	1.000	0.0	0.0	1.000
3.200	158.6	10.36	0.72	3000.0	0.0	0.0	1.000	0.0	0.0	1.000	894.7	0.0	0.0	1.000	0.0	0.0	1.000
3.250	159.0	9.20	0.72	3000.0	0.0	0.0	1.000	0.0	0.0	1.000	894.7	0.0	0.0	1.000	0.0	0.0	1.000
3.300	159.5	8.05	0.72	3000.0	0.0	0.0	1.000	0.0	0.0	1.000	894.7	0.0	0.0	1.000	0.0	0.0	1.000
3.350	159.8	6.89	0.72	3000.0	0.0	0.0	1.000	0.0	0.0	1.000	894.7	0.0	0.0	1.000	0.0	0.0	1.000
3.400	160.2	5.73	0.73	3000.0	0.0	0.0	1.000	0.0	0.0	1.000	894.7	0.0	0.0	1.000	0.0	0.0	1.000
3.450	160.4	4.55	0.73	3000.0	0.0	0.0	1.000	0.0	0.0	1.000	894.7	0.0	0.0	1.000	0.0	0.0	1.000
3.500	160.6	3.37	0.74	3000.0	0.0	0.0	1.000	0.0	0.0	1.000	894.7	0.0	0.0	1.000	0.0	0.0	1.000
3.550	160.7	2.16	0.75	3000.0	0.0	0.0	1.000	0.0	0.0	1.000	894.7	0.0	0.0	1.000	0.0	0.0	1.000
3.600	160.8	0.95	0.76	3000.0	0.0	0.0	1.000	0.0	0.0	1.000	894.7	0.0	0.0	1.000	0.0	0.0	1.000

[PX 129, p 5]

[PX 129, p 6]

E-656

[PX 129, p 6]

3000.	5.33	7.87	18.00	98.65	.030	.020	.030	0.51	0.39	250.0	150.0	0.92	700.	.344	20.0				
0.000	0.0	36.67	0.01	0.0	36.67	0.00	0.000	36.67	0.00	0.000	0.0	36.67	0.00	0.000	36.67	0.00	0.000		
0.050	1.8	36.36	0.37	663.6	34.97	-1.29	0.038	34.97	-1.29	0.038	398.2	35.32	-1.07	0.029	35.32	-1.07	0.029		
0.100	3.6	35.55	0.61	1180.4	32.64	-1.62	0.082	32.64	-1.62	0.082	519.2	34.00	-0.89	0.044	34.00	-0.89	0.044		
0.150	5.4	34.43	0.77	1582.9	29.31	-3.29	0.148	29.31	-3.29	0.148	602.2	32.37	-1.13	0.060	32.37	-1.13	0.060		
0.200	7.1	33.18	0.77	1896.3	16.07	-13.63	0.515	16.07	-13.63	0.515	666.9	30.42	-1.30	0.084	30.42	-1.30	0.084		
0.250	8.7	31.97	0.75	2140.5	0.0	0.0	1.000	0.0	0.0	1.000	717.3	28.11	-1.70	0.122	28.11	-1.70	0.122		
0.300	10.3	30.75	0.76	2330.6	0.0	0.0	1.000	0.0	0.0	1.000	756.6	23.52	-4.47	0.237	23.52	-4.47	0.237		
0.350	11.8	29.53	0.76	2478.7	0.0	0.0	1.000	0.0	0.0	1.000	787.1	13.73	-7.65	0.536	13.73	-7.65	0.536		
0.400	13.2	28.30	0.30	924.6	5.38	20.98	0.809	5.38	20.98	0.809	466.4	5.00	0.07	0.824	5.00	0.07	0.824		
0.450	14.6	27.41	0.45	752.1	26.67	-2.85	0.026	26.67	-2.85	0.026	430.8	714.29	3.32	0.479	14.29	3.32	0.479		
0.500	15.9	26.09	0.98	2315.1	20.84	-7.52	0.201	20.84	-7.52	0.201	753.4	10.60	-5.82	0.594	10.60	-5.82	0.594		
0.550	17.2	24.84	0.44	587.4	24.28	0.25	0.023	24.28	0.25	0.023	352.4	9.57	6.31	0.615	9.57	6.31	0.615		
0.600	18.4	23.70	1.02	2230.9	20.37	-4.69	0.141	20.37	-4.69	0.141	736.0	13.26	-2.64	0.439	13.26	-2.64	0.439		
0.650	19.6	22.17	0.51	1314.4	6.69	13.07	0.699	6.69	13.07	0.699	546.8	9.21	2.71	0.584	9.21	2.71	0.584		
0.700	20.6	20.69	0.99	2315.7	16.19	-10.60	0.218	16.19	-10.60	0.218	753.5	12.51	-1.91	0.394	12.51	-1.91	0.394		
0.750	21.6	19.23	0.83	1389.7	0.20	4.11	0.990	0.20	4.11	0.990	562.4	9.22	3.08	0.521	9.22	3.08	0.521		
0.800	22.6	17.90	0.82	2419.8	0.0	0.0	1.000	0.0	0.0	1.000	775.0	12.17	-2.04	0.319	12.17	-2.04	0.319		
0.850	23.4	16.61	0.79	1280.7	0.20	4.00	0.988	0.20	4.00	0.988	539.9	9.77	4.11	0.411	9.77	4.11	0.411		
0.900	24.2	15.32	0.78	2463.8	0.0	0.0	1.000	0.0	0.0	1.000	784.0	13.01	-1.90	0.150	13.01	-1.90	0.150		
0.950	25.0	14.09	0.75	1633.8	0.0	0.0	1.000	0.0	0.0	1.000	612.7	8.72	1.70	0.380	8.72	1.70	0.380		
1.000	25.6	12.89	0.75	2349.1	0.0	0.0	1.000	0.0	0.0	1.000	760.4	11.12	-1.72	0.136	11.12	-1.72	0.136		
1.050	26.3	11.70	0.73	1919.2	0.0	0.0	1.000	0.0	0.0	1.000	671.6	10.38	-0.35	0.113	10.38	-0.35	0.113		
1.100	26.8	10.55	0.71	1760.9	0.0	0.0	1.000	0.0	0.0	1.000	639.0	9.55	-0.91	0.094	9.55	-0.91	0.094		
1.150	27.3	9.41	0.78	1219.4	7.59	10.43	0.193	7.59	10.43	0.193	527.2	8.78	-0.94	0.067	8.78	-0.94	0.067		
1.200	27.8	8.61	0.41	712.6	8.30	-0.48	0.037	8.30	-0.48	0.037	422.6	8.19	-0.45	0.050	8.19	-0.45	0.050		
1.250	28.2	8.17	0.19	323.4	8.05	-0.21	0.015	8.05	-0.21	0.015	194.0	8.01	-0.22	0.019	8.01	-0.22	0.019		
1.300	28.6	7.94	0.21	373.8	7.82	-0.54	0.017	7.82	-0.54	0.017	224.3	7.78	-0.57	0.019	7.78	-0.57	0.019		
1.350	29.0	6.99	0.82	1936.4	4.50	-10.95	0.356	4.50	-10.95	0.356	675.2	6.51	-0.92	0.067	6.51	-0.92	0.067		
1.400	29.3	5.73	0.80	2737.0	0.0	0.0	1.000	0.0	0.0	1.000	840.4	5.19	-0.80	0.096	5.19	-0.80	0.096		
1.450	29.5	4.43	0.82	2948.4	0.0	0.0	1.000	0.0	0.0	1.000	884.1	3.91	-0.80	0.118	3.91	-0.80	0.118		
1.500	29.7	3.10	0.82	2693.2	0.0	0.0	1.000	0.0	0.0	1.000	831.4	2.30	-0.67	0.263	2.30	-0.67	0.263		
1.550	29.8	1.83	0.80	2235.1	0.0	0.0	1.000	0.0	0.0	1.000	736.9	1.65	-0.78	0.110	1.65	-0.78	0.110		

PLAINTIFF'S EXHIBIT 130

May 7, 1965

PR
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4/4/74

ANTI-SKID CONTROL

I. General Description of Major Assemblies

A. Sensing Unit

This unit is basically designed with two control systems, mechanical and electrical. The two systems perform specific functions which are interwoven to obtain a pumping cycle of brake pressure in conjunction with the other major assemblies.

1. Mechanical System

The mechanical system is driven by means of a flexible cable which connects the sensing unit and gear box described below. The cable drives a shaft with a delrin gear, which drives a cam gear mounted on a governor shaft. The cam gear drives the governor shaft which is of two piece construction. The governor weights are mounted on a collapsible cradle which is pinned to the fixed and movable portions of the governor shaft. The movable portion of the governor shaft is attached to the lever arm of a rotary valve.

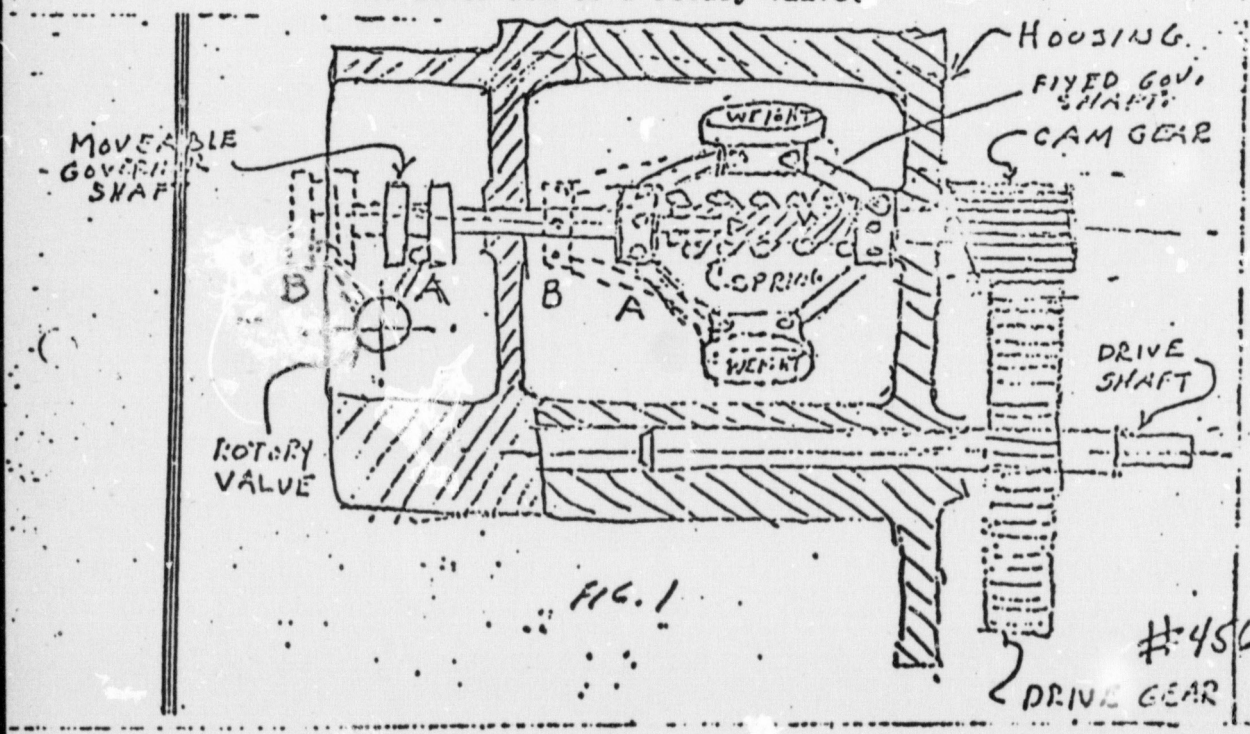


FIG. 1

#45

When the drive gear is rotating at high speeds, the governor weights hold the movable shaft in Position "A". The rotary valve is also in Position "A" which opens the atmospheric port of the rotary valve allowing atmospheric pressure to enter the vacuum accumulator described below. While the valve is in this position, full braking pressure is applied to the vehicle brake drums which locks the wheels. As the drive train is slowed down by the braking action, the governor collapses due to the force exerted by the return spring and the lack of sufficient centrifical force in the governor weights to overcome the spring force. As the movable portion of the governor shaft shifts to Position "B", the rotary valve is turned, closing the atmospheric port and opening the vacuum port. This allows vacuum to enter the vacuum accumulator which reduces the brake pressure and unlocks the wheels. As the wheels start turning, motion is transmitted to the governor shaft and the weights shift the movable shaft back to Position "A". This action applies full braking power and locks the vehicle wheels. The unit will continue to modulate the brake pressure in this manner until the vehicle speed is reduced to approximately 12 m.p.h. At this speed, the governor weights cannot return the valve to Position "A", and the electrical circuit takes over as described below to return full braking power to the vehicle.

2. Electrical System

The electrical system is composed of a micro switch, hydraulic pressure switch, solenoid and reverse disconnect contact. The solenoid is constructed with a spring loaded plunger and is normally de-energized. This system is designed to perform the following functions.

a. Prevent the unit from cycling during normal stops.

b. Trigger the unit when lock-up occurs.

c. Allow the unit to cycle mechanically on high coefficient of friction road conditions.

d. Return full braking power when governor shaft speed is too low to accomplish this.

e. Cycle the unit electrically on low coefficient of friction road conditions.

f. Prevent unit from cycling in reverse.

The following are schematic diagrams of the system.

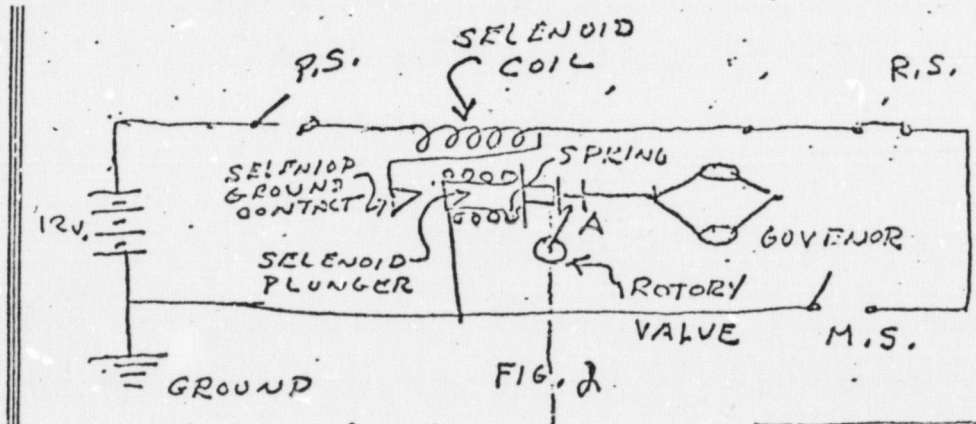
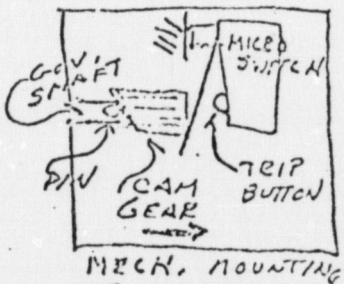


FIG. 2

P.S. = PRESSURE SWITCH
R.S. = REVERSE SWITCH
M.S. = MICRO SWITCH



MECH. MOUNTING OF MICRO SWITCH

FIG. 3

Figure 2 shows the system in the non-activated state with the vehicle moving and no braking being applied. Notice that the spring loaded solenoid plunger keeps the rotary valve in the atmospheric position which allows braking power at low speeds when brakes are applied during normal driving. The reverse switch is closed when the vehicle is traveling forward or stopped and only opens when the vehicle is going in reverse. The micro switch is open during normal

driving and braking which prevents the unit from cycling. The pressure switch is normally open and closes only when braking is applied. Figure 3 shows the mechanical means used to close the micro switch when the brakes are jammed on. When the vehicle is moving and the brakes are jammed on, the cam gear is moved in the direction shown by means of the camming action of the pin on the cam. The micro switch trip button is triggered and the switch closes.

As mentioned above, the pressure switch is closed when the brake pressure is applied and the electrical circuit is closed. The current flowing through this circuit energizes the solenoid coil and the plunger is retracted. The solenoid ground circuit is completed and the solenoid stays retracted, allowing the mechanical system to operate as previously described even though the micro switch opens (Figure 4).

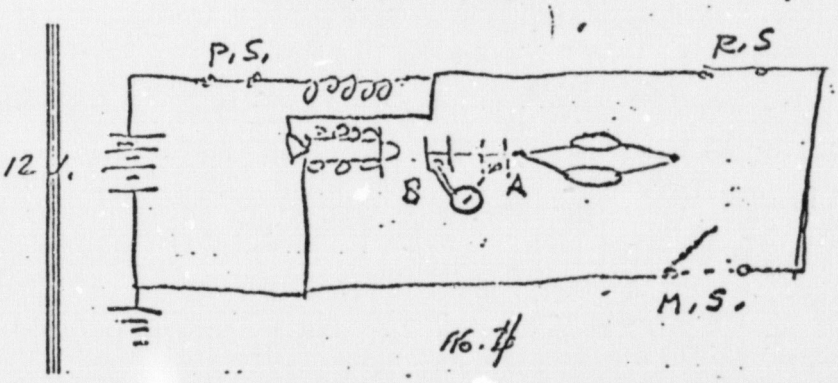


Fig. 4

When the vehicle speed is reduced to approximately 12 m.p.h., the pressure in the brake system will fall below the pressure switch setting and the circuit is broken. The solenoid is de-energized and the spring loaded plunger shifts the rotary valve to Position "A" (Figure 2), and full braking power is returned to the system. On very low coefficient of friction road conditions, the pressure may drop below the switch setting during cycling. When this occurs, the unit will cycle electrically off the pressure and micro switches.

B. Perma-Vac Unit

This unit is designed to perform the following functions.

1. Check off the brake pedal pressure when wheel lock-up occurs.

2. Reduce line brake pressure to release locked wheels.

3. Return brake pressure to lock wheels during cycle.

4. Return hydraulic system back to normal operation after vehicle has come to rest.

There are two varieties available. One type is equipped with a single piston and is used on vehicles with standard type master cylinders. The other variety is designed with a dual piston to accommodate vehicles with dual master cylinders. The basic operating principles are the same in each case. However, the output pressures and displacement capabilities are somewhat different. The single piston unit (Figure 5) will be described.

When the vehicle engine is running, vacuum enters the transfer valve directly from the engine manifold as shown (Figure 5). It goes through an opening in the valve and enters the chamber in front of the spring loaded diaphragm. This aids the spring to overcome the force exerted on the piston when braking is applied and prevents the piston from retracting to Position "B" until a predetermined pressure is reached in the hydraulic system or wheel lock-up occurs. When this pressure (check off pressure) is reached, the piston will retract, allowing the check valve to seat and thereby isolating the master cylinder and brake pedal from the system. At the same time, the Sensing Unit will react to wheel lock-up by turning the rotary valve as described previously, which allows vacuum to enter the rear chamber of the Perma-Vac Unit. Since the diaphragm chamber of the transfer valve is teed into this line, vacuum will enter the transfer valve and retract the valve. The valve will close off the vacuum intake port and open the atmospheric port exposing the front chamber of the Perma-Vac to atmospheric pressure. The vacuum pressure in the rear chamber of the cam overcomes the spring force

and the piston moves to Position "B". The movement of the piston allows brake fluid to enter the cylinder bore. The hydraulic brake line pressure is reduced by this action and the wheels are unlocked. When the wheels start rotating, the governor action of the Sensing Unit turns the rotary valve which allows atmospheric pressure to enter the rear chamber of the Perma-Vac. Atmospheric pressure is also allowed to enter the diaphragm chamber of the transfer valve and the valve is returned to its original position by the return spring. The atmospheric port of the transfer valve is closed and the vacuum port is opened allowing vacuum to enter the front chamber of the Perma-Vac Can. Vacuum on the front side of the can diaphragm and atmospheric pressure on the rear side aids the return spring to return the piston to Position "A", which increases the brake line pressure and locks the wheels. This cycle is repeated until the vehicle has come to rest. At this time, the piston returns to its original position and unseats the check valve which returns the hydraulic system back to normal.

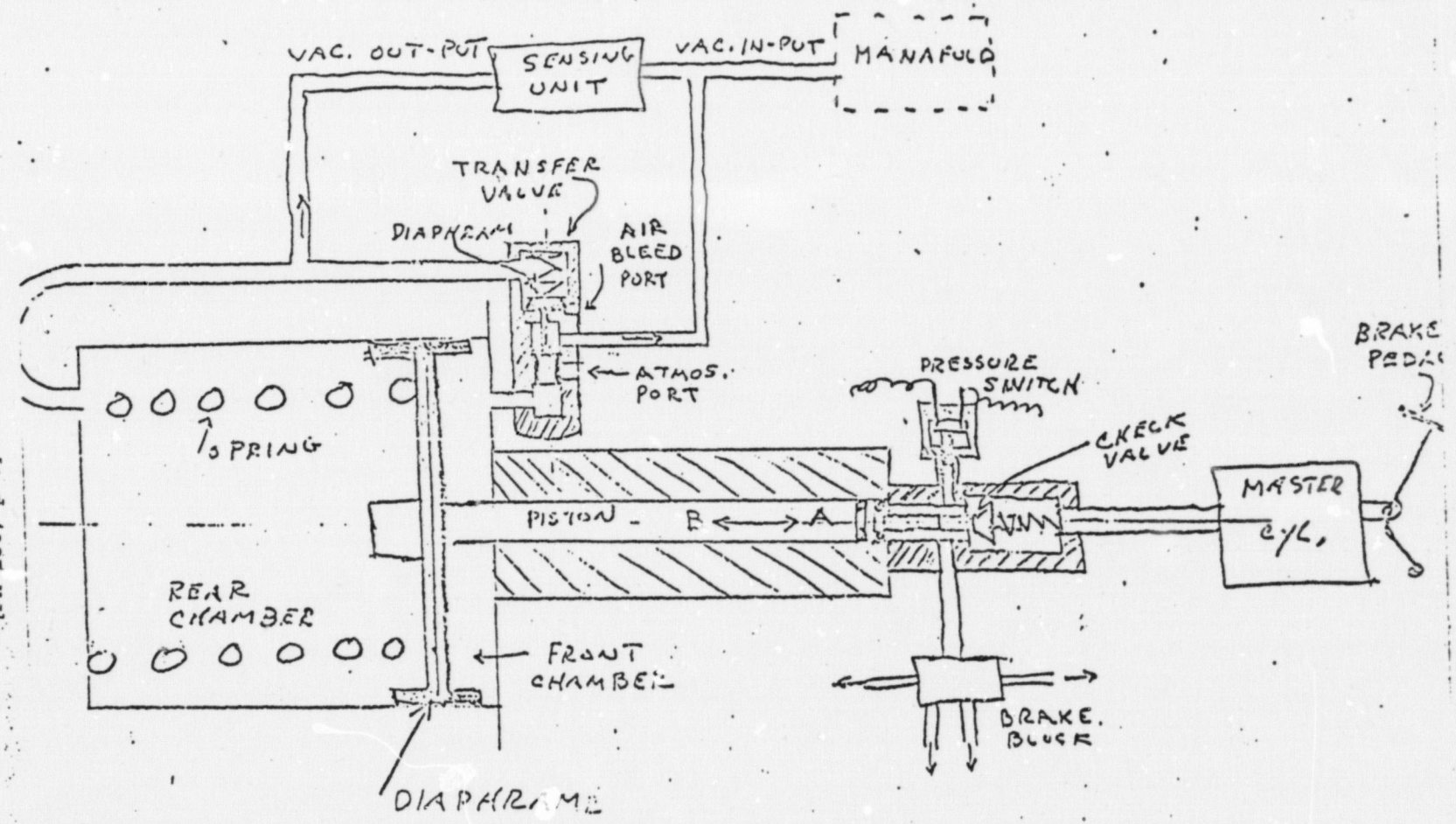


FIG. 5

[PX 130, p 7]

[PX 130, p 7]

E-663

C. Transfer Valve

This assembly is designed to regulate the pressure in the front chamber of the Perma-Vac Unit. Figure 6 shows the unit in its normal operating position when the Anti-Skid Device is not being utilized. Figure 7 shows the unit during the brake releasing cycle of the Perma-Vac.

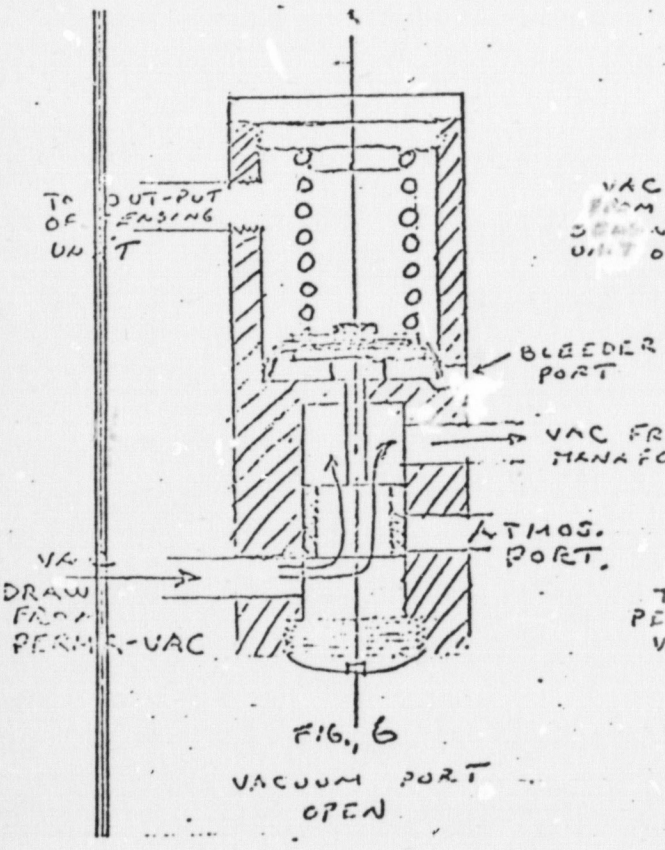


FIG. 6
VACUUM PORT OPEN

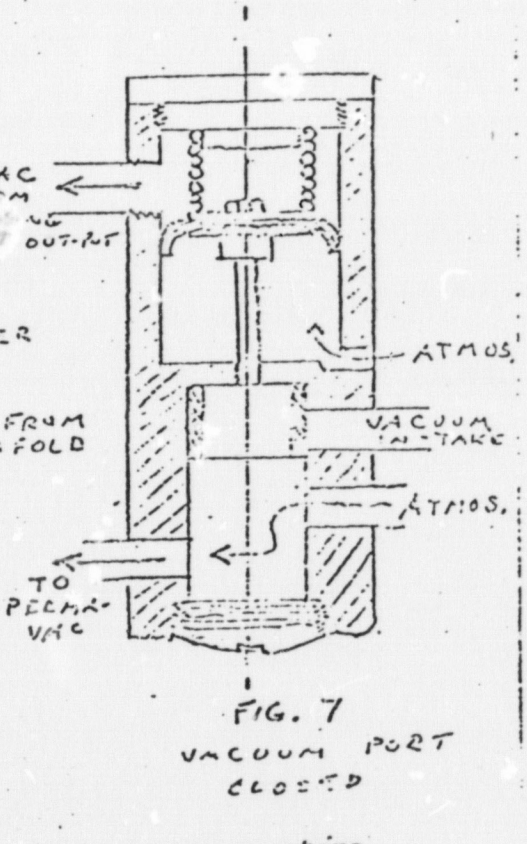


FIG. 7
VACUUM PORT CLOSED

When the vehicle engine is running, vacuum enters the valve from the engine manifold (Figure 6) and goes through an opening in the valve and enters the front chamber of the Perma-Vac Unit. The atmospheric port is closed as shown. As soon as the Perma-Vac Unit is cycled by the Sensing Unit, vacuum enters the top of the transfer valve (Figure 7) and

the valve is retracted, thereby closing the vacuum intake port and opening the atmospheric port to the front of the Perma-Vac Unit. When atmospheric pressure is again applied to the rear of the Perma-Vac, by the turning of the rotary valve in the Sensing Unit, it also enters the top of the transfer valve. When this happens, the return spring moves the valve back to its original position and the cycle is completed. The transfer valve will cycle in the above manner each time the Perma-Vac Unit cycles.

D. Gear Box, Flexible Drive Cable and Adaptor

These components comprise the mechanical drive system used to transmit rotation to the governor shaft of the Sensing Unit (Figure 8)..

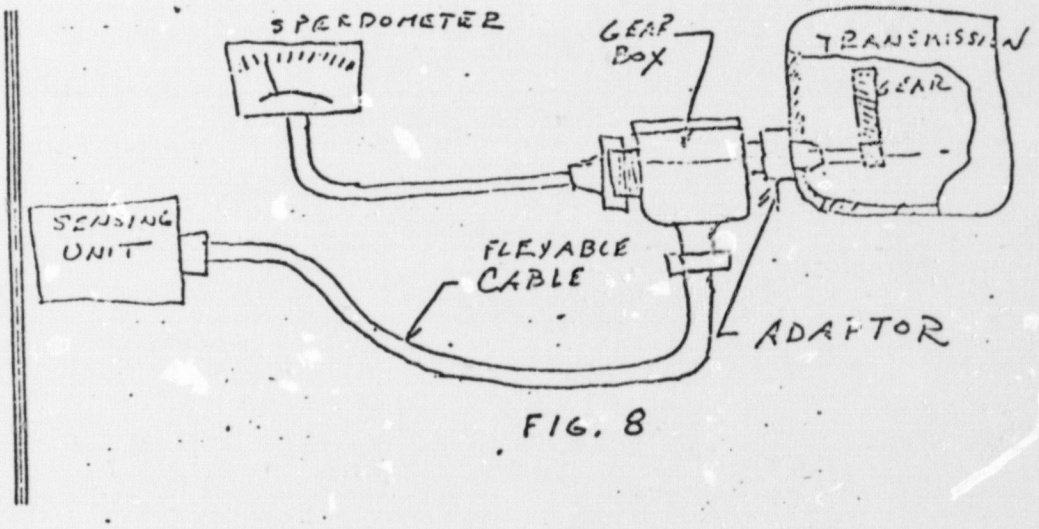


FIG. 8

The gear box (Figure 9) is used to step-up the speed ratio from the transmission in order to gain greater sensitivity in the Sensing Unit. When the rear wheels lock-up, torque is transmitted through the adaptor, gear box and flexible shaft to the Sensing Unit. This action triggers the micro switch in the Sensing Unit as previously described.

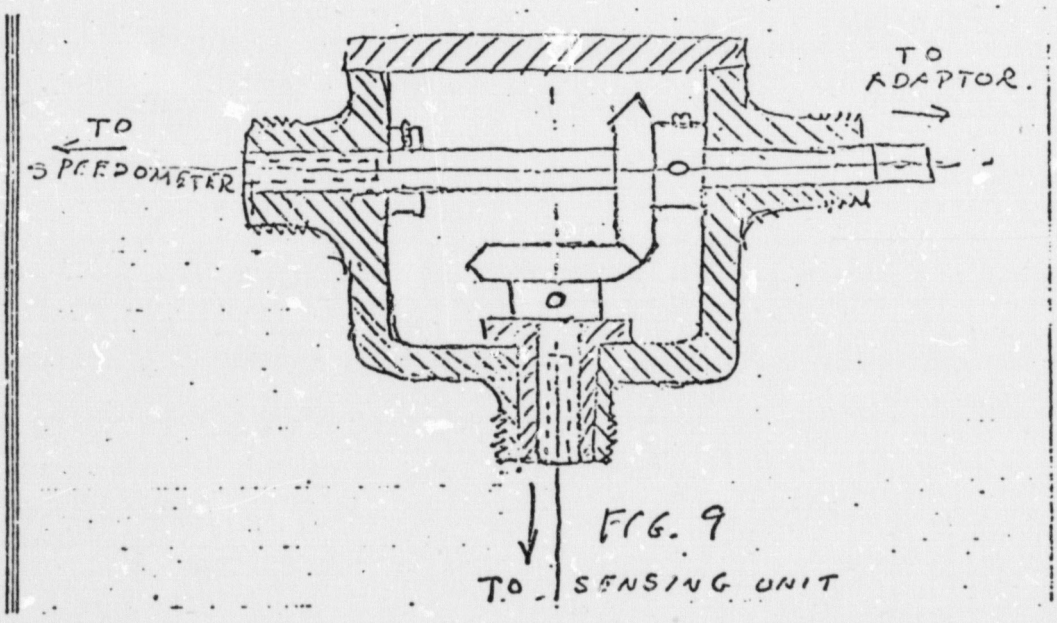


FIG. 9

E. Pressure Switch

The basic function of this assembly is to break the electrical circuit and return the system back to normal braking status after a panic stop. The unit is constructed with a small piston which is spring loaded. The piston moves against the spring force when hydraulic pressure is applied, thereby opening and closing electrical contacts. The switch is pre-set at the factory and should not be re-set in the field. The following is a schematic drawing of the switch.

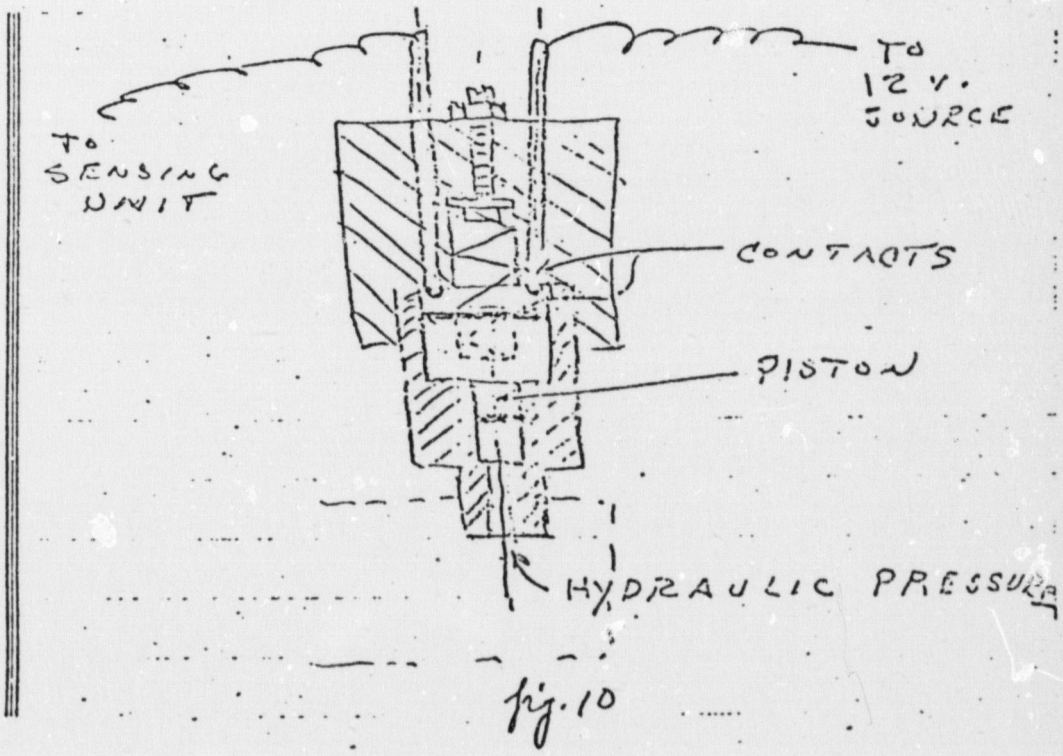


fig. 10

II. Performance Criteria

A. Operating Range

The unit is designed to cycle within the following ranges when braking is applied abruptly and both rear wheels lock-up.

1. Temperature: 200°F to -30°F (*)

2. Speed:

   a. Maximum: 80 m.p.h. (**)

   b. Minimum: 10 m.p.h.

3. Cycles per second:

   Dry Pavement: 1-2.1

   Wet, Gravel, Snow or Ice: 1.3-2.4

4. Minimum Vacuum: 15 in. Hg. and an excess of 12 cu. ft. per minute in volume of vacuum.

5. Minimum Voltage: 11 Volts D. C.

(**) Vehicles have not been tested over this speed.

(*) This information is based on tests conducted by Perma. Environmental tests at this temperature have not been made by Singer to date.

B. Application Requirements

Vehicles must have:

1. Hydraulic operating drum type brakes.

2. 12 Volt D. C. electrical system.

3. Speedometer take off at transmission.

4. Rear wheel drive.

5. Internal combustion engine which creates a minimum of 15 inches of vacuum and an excess of 12 cu. ft. per minute in volume of vacuum.

6. Vehicle brake system must be in good condition, properly adjusted and bled.

C. Limitations of Unit

1. Steering Control

a. By steering control we mean the operator can maneuver the vehicle during braking when trying to avoid a collision. When stopping the vehicle on two lane roads where straight stopping is essential, the unit enables the operator to stop the vehicle within 0 to 5° with respect to the road.

The unit affords steering control on all road conditions except ice. The unit will not provide steering control under conditions where steering control would not be available even without brakes being applied due to extremely low road friction; centrifugal skids due to excessive high speeds on sharp curves or high acceleration on slippery roads. These conditions usually occur on wet ice, snow on ice, glazed ice and ice on a crowned road.

b. On mixed road conditions, two right wheels on snow or ice and two left wheels on dry pavement, the unit will enable the operator to bring the vehicle to rest at an angle of 0-5° with respect to the road, depending on the amount of correction introduced by the operator.

2. Stopping Distances with Unit

a. Dry Road Conditions

1. 50 m.p.h. - Increase by .8 to 20%

2. 30 m.p.h. - Increase by 4.4 to 20%

b. Low Coefficient Road Conditions

1. 50 m.p.h. - Decrease by 0 to 10%

2. 30 m.p.h. - Increase by 6 to 15%

3. Ability to Cycle

a. Fooling the unit:

It is possible under certain conditions to lock-up the wheels without cycling the unit. This characteristic is termed "fooling the unit". As stated previously, the brakes must be applied abruptly in order to trip the micro switch in the Sensing Unit. This abrupt braking action is generally applied during emergency stops. However, drivers have been told to apply brakes slowly on slippery road conditions to avoid wheel lock-up. This is practiced by most experienced drivers and therefore they must be informed that the unit will not cycle under these circumstances.

b. Loss of vacuum:

The unit will not cycle if the vehicle stalls or a loss of vacuum to the unit occurs due to hose breakage or excessive leakage in the vacuum system of the unit. If the loss of vacuum occurs before the brakes are applied, during a cycle or prior to reaching the check-off pressure, a loss of braking power will result. The calculated available pressure, disregarding friction is: 450 p.s.i. for a single piston unit, and 485 p.s.i. for a dual unit. This pressure may or may not lock-up the wheels, depending on the speed and condition of the brake linings at the time the failure occurs.

c. Malfunctions due to improper settings, failure of components or breakage of electrical circuits are discussed in detail in Article III (Trouble Shooting and Repair).

d. The unit will function only on those vehicles officially prototyped by Singer. Adapting the unit to vehicles not included on the official list must be discouraged, in that brake systems react differently on each vehicle and design requirements also vary. Under no circumstances is the present design configuration to be used on vehicles equipped with disc type brake systems.

4. Road Test for Cycling

a. Normal Braking

With a vehicle speed of approximately 30 m.p.h., apply gradual braking as is normally done when stopping in traffic or a light. The unit should not cycle when this is done on dry road conditions.

b. Emergency Braking

With a vehicle speed of approximately 30 m.p.h. on dry road conditions, apply the brake abruptly. The unit should cycle in a pattern as shown.

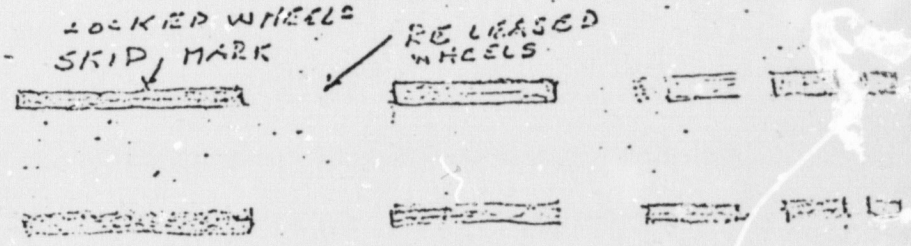


fig. 11

Notice that the length of tire skid marks and the distance between marks diminsh as the vehicle speed is reduced. The length of these pulses are a function of road coefficient of friction, tire condition, weight distribution and other variables. Therefore, they will vary between different runs or stops and vehicles.

After the vehicle has come to rest the system should return to normal braking condition. Part (a.) should be repeated to check this feature.

When snow or wet pavement is available the above checks should also be made for these road conditions. Discretion should be used in chosing the test speed.

c. Minimum Cycling Speed

At a speed of 10 m.p.h., apply the brakes abruptly. The unit should cycle. If this is done on dry road conditions, one pulse may only occur and it will be difficult to determine whether or not the unit actually cycled. Therefore, it is suggested that this test be made on gravel when wet road conditions, snow or ice are not available.

PLAINTIFF'S EXHIBIT 131

May 7, 1965 PR

ANTI-SKID CONTROL

I. General Description of Major Assemblies

A. Sensing Unit

This unit is basically designed with two control systems, mechanical and electrical. The two systems perform specific functions which are interwoven to obtain a pumping cycle of brake pressure in conjunction with the other major assemblies.

1. Mechanical System

The mechanical system is driven by means of a flexible cable which connects the sensing unit and gear box described below. The cable drives a shaft with a delrin gear, which drives a cam gear mounted on a governor shaft. The cam gear drives the governor shaft which is of two piece construction. The governor weights are mounted on a collapsible cradle which is pinned to the fixed and movable portions of the governor shaft. The movable portion of the governor shaft is attached to the lever arm of a rotary valve.

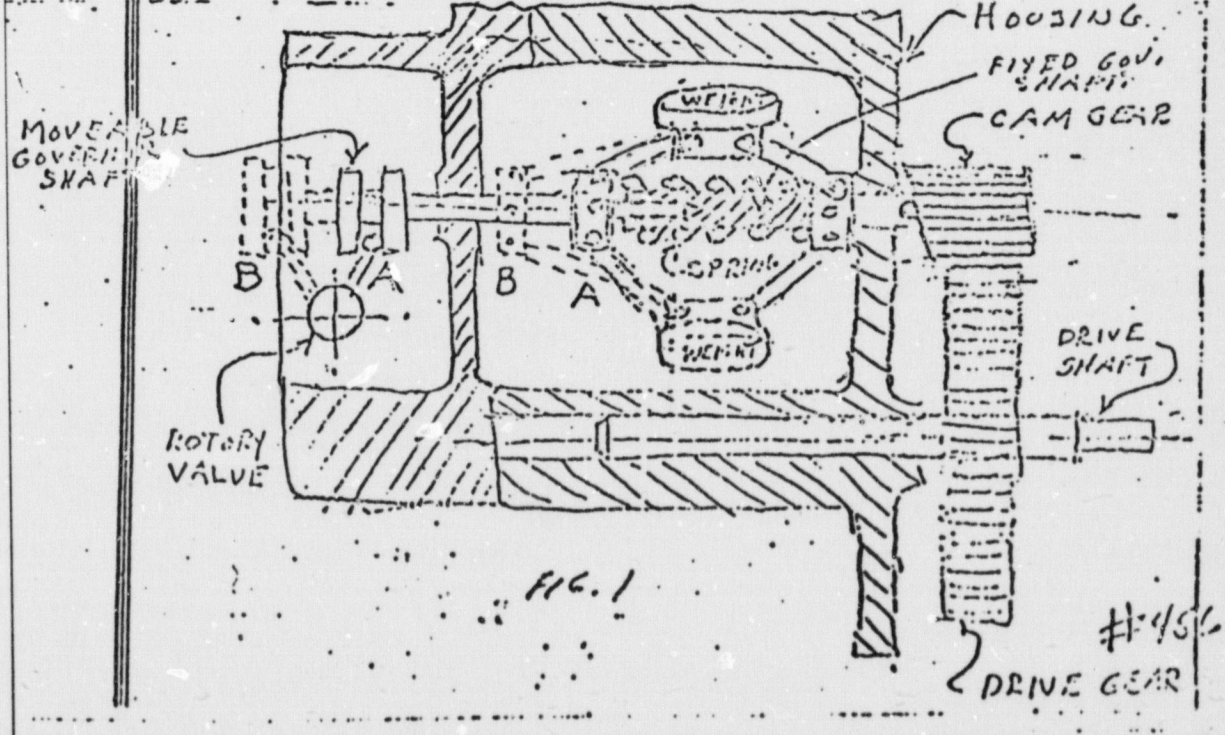


FIG. 1

#1454

When the drive gear is rotating at high speeds, the governor weights hold the movable shaft in Position "A". The rotary valve is also in Position "A" which opens the atmospheric port of the rotary valve allowing atmospheric pressure to enter the vacuum accumulator described below. While the valve is in this position, full braking pressure is applied to the vehicle brake drums which locks the wheels. As the drive train is slowed down by the braking action, the governor collapses due to the force exerted by the return spring and the lack of sufficient centrifical force in the governor weights to overcome the spring force. As the movable portion of the governor shaft shifts to Position "B", the rotary valve is turned, closing the atmospheric port and opening the vacuum port. This allows vacuum to enter the vacuum accumulator which reduces the brake pressure and unlocks the wheels. As the wheels start turning, motion is transmitted to the governor shaft and the weights shift the movable shaft back to Position "A". This action applies full braking power and locks the venicle wheels. The unit will continue to modulate the brake pressure in this manner until the vehicle speed is reduced to approximately 12 m.p.h. At this speed, the governor weights cannot return the valve to Position "A", and the electrical circuit takes over as described below to return full braking power to the vehicle.

2. Electrical System

The electrical system is composed of a micro switch, hydraulic pressure switch, solenoid and reverse disconnect contact. The solenoid is constructed with a spring loaded plunger and is normally de-energized. This system is designed to perform the following functions.

a. Prevent the unit from cycling during normal stops.

b. Trigger the unit when lock-up occurs.

c. Allow the unit to cycle mechanically on high coefficient of friction road conditions.

d. Return full braking power when governor shaft speed is too low to accomplish this.

e. Cycle the unit electrically on low coefficient of friction road conditions.

f. Prevent unit from cycling in reverse.

The following are schematic diagrams of the system.

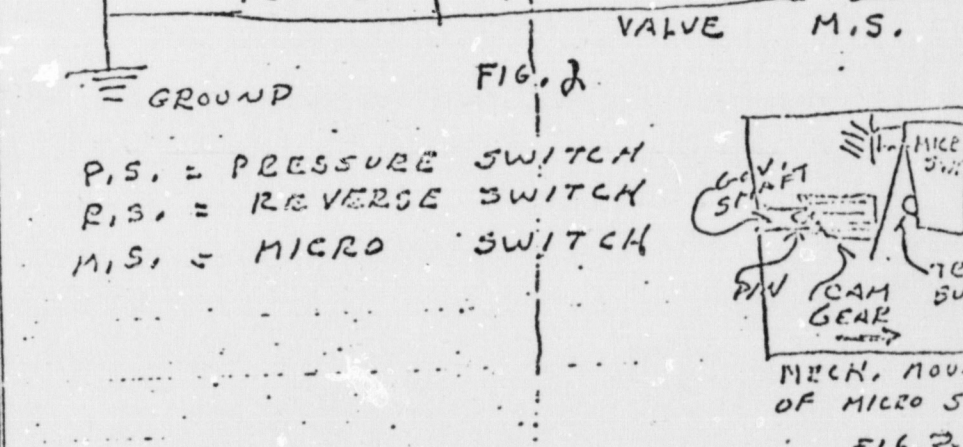
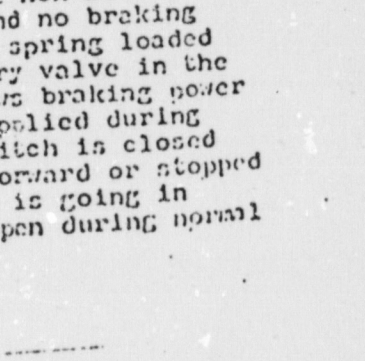


FIG. 2

P.S. = PRESSURE SWITCH
R.S. = REVERSE SWITCH
M.S. = MICRO SWITCH



MECH. MOUNTING OF MICRO SWITCH

FIG. 3

Figure 2 shows the system in the non-activated state with the vehicle moving and no braking being applied. Notice that the spring loaded solenoid plunger keeps the rotary valve in the atmospheric position which allows braking power at low speeds when brakes are applied during normal driving. The reverse switch is closed when the vehicle is traveling forward or stopped and only opens when the vehicle is going in reverse. The micro switch is open during normal

driving and braking which prevents the unit from cycling. The pressure switch is normally open and closes only when braking is applied. Figure 3 shows the mechanical means used to close the micro switch when the brakes are jammed on. When the vehicle is moving and the brakes are jammed on, the cam gear is moved in the direction shown by means of the camming action of the pin on the cam. The micro switch trip button is triggered and the switch closes.

As mentioned above, the pressure switch is closed when the brake pressure is applied and the electrical circuit is closed. The current flowing through this circuit energizes the solenoid coil and the plunger is retracted. The solenoid ground circuit is completed and the solenoid stays retracted, allowing the mechanical system to operate as previously described even though the micro switch opens (Figure 4).

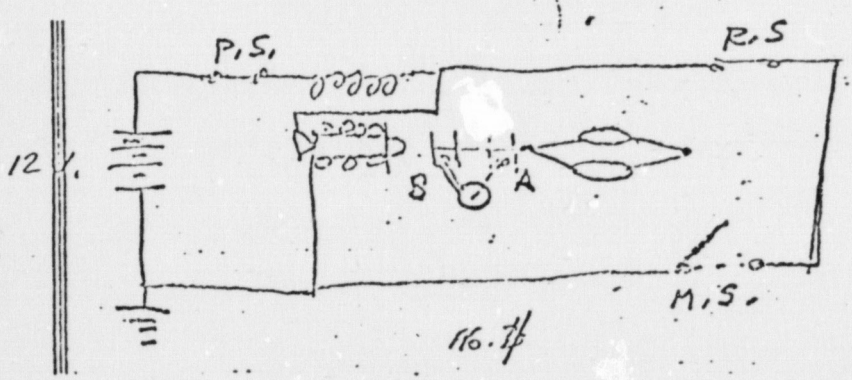


Fig. 4

When the vehicle speed is reduced to approximately 12 m.p.h., the pressure in the brake system will fall below the pressure switch setting and the circuit is broken. The solenoid is de-energized and the spring loaded plunger shifts the rotary valve to Position "A" (Figure 2), and full braking power is returned to the system. On very low coefficient of friction road conditions, the pressure may drop below the switch setting during cycling. When this occurs, the unit will cycle electrically off the pressure and micro switches.

B. Perma-Vac Unit

This unit is designed to perform the following functions.

1. Check off the brake pedal pressure when wheel lock-up occurs.

2. Reduce line brake pressure to release locked wheels.

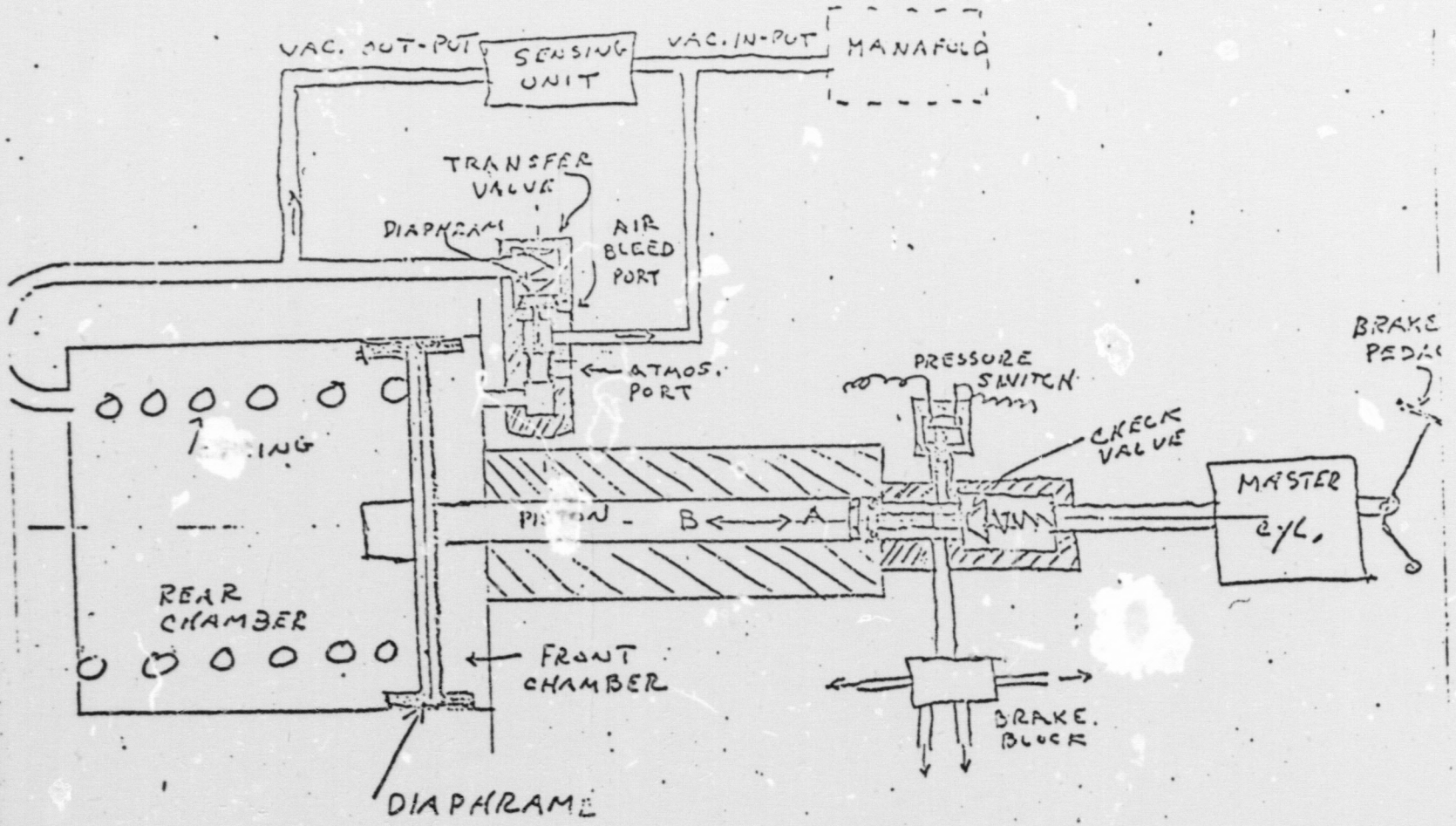
3. Return brake pressure to lock wheels during cycle.

4. Return hydraulic system back to normal operation after vehicle has come to rest.

There are two varieties available. One type is equipped with a single piston and is used on vehicles with standard type master cylinders. The other variety is designed with a dual piston to accommodate vehicles with dual master cylinders. The basic operating principles are the same in each case. However, the output pressures and displacement capabilities are somewhat different. The single piston unit (Figure 5) will be described.

When the vehicle engine is running, vacuum enters the transfer valve directly from the engine manifold as shown (Figure 5). It goes through an opening in the valve and enters the chamber in front of the spring loaded diaphragm. This aids the spring to overcome the force exerted on the piston when braking is applied and prevents the piston from retracting to Position "B" until a predetermined pressure is reached in the hydraulic system or wheel lock-up occurs. When this pressure (check off pressure) is reached, the piston will retract, allowing the check valve to seat and thereby isolating the master cylinder and brake pedal from the system. At the same time, the Sensing Unit will react to wheel lock-up by turning the rotary valve as described previously, which allows vacuum to enter the rear chamber of the Perma-Vac Unit. Since the diaphragm chamber of the transfer valve is teed into this line, vacuum will enter the transfer valve and retract the valve. The valve will close off the vacuum intake port and open the atmospheric port exposing the front chamber of the Perma-Vac to atmospheric pressure. The vacuum pressure in the rear chamber of the cam overcomes the spring force

and the piston moves to Position "B". The movement of the piston allows brake fluid to enter the cylinder bore. The hydraulic brake line pressure is reduced by this action and the wheels are unlocked. When the wheels start rotating, the governor action of the Sensing Unit turns the rotary valve which allows atmospheric pressure to enter the rear chamber of the Perma-Vac. Atmospheric pressure is also allowed to enter the diaphragm chamber of the transfer valve and the valve is returned to its original position by the return spring. The atmospheric port of the transfer valve is closed and the vacuum port is opened allowing vacuum to enter the front chamber of the Perma-Vac Can. Vacuum on the front side of the can diaphragm and atmospheric pressure on the rear side aids the return spring to return the piston to Position "A", which increases the brake line pressure and locks the wheels. This cycle is repeated until the vehicle has come to rest. At this time, the piston returns to its original position and unseats the check valve which returns the hydraulic system back to normal.



FIG, 5

E-679 [PX 131, p 7]
[PX 131, p 7]

C. Transfer Valve

This assembly is designed to regulate the pressure in the front chamber of the Perma-Vac Unit. Figure 6 shows the unit in its normal operating position when the Anti-Skid Device is not being utilized. Figure 7 shows the unit during the brake releasing cycle of the Perma-Vac.

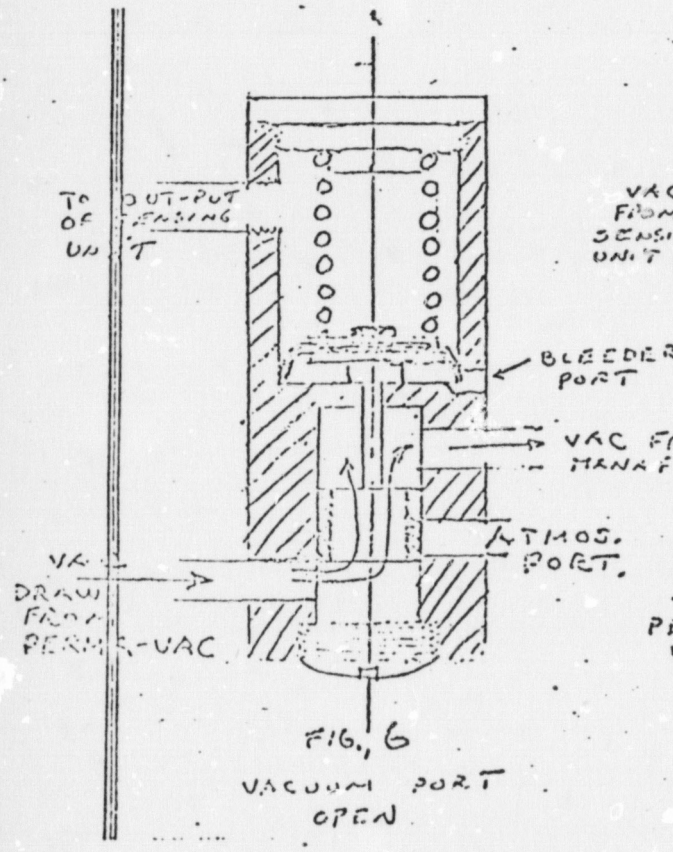


FIG. 6
VACUUM PORT OPEN

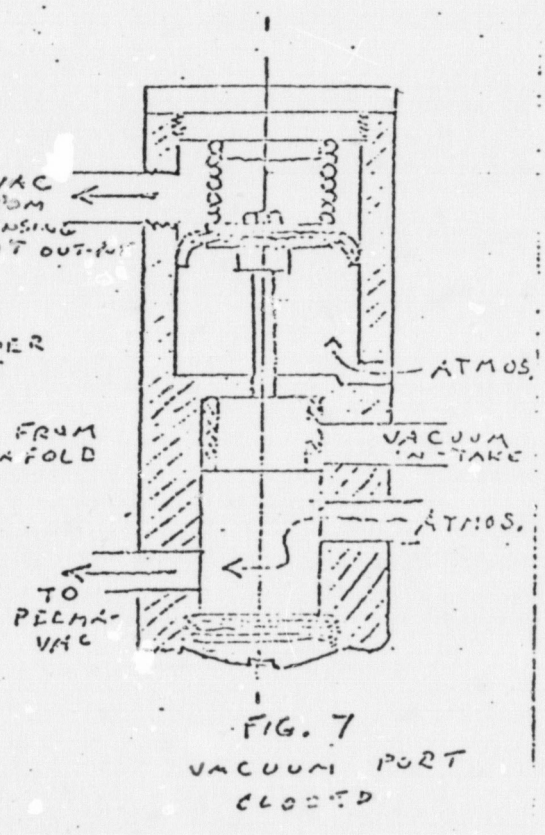


FIG. 7
VACUUM PORT CLOSED

When the vehicle engine is running, vacuum enters the valve from the engine manifold (Figure 6) and goes through an opening in the valve and enters the front chamber of the Perma-Vac Unit. The atmospheric port is closed as shown. As soon as the Perma-Vac Unit is cycled by the Sensing Unit, vacuum enters the top of the transfer valve (Figure 7) and

the valve is retracted, thereby closing the vacuum intake port and opening the atmospheric port to the front of the Perma-Vac Unit. When atmospheric pressure is again applied to the rear of the Perma-Vac, by the turning of the rotary valve in the Sensing Unit, it also enters the top of the transfer valve. When this happens, the return spring moves the valve back to its original position and the cycle is completed. The transfer valve will cycle in the above manner each time the Perma-Vac Unit cycles.

D. Gear Box, Flexible Drive Cable and Adaptor

These components comprise the mechanical drive system used to transmit rotation to the governor shaft of the Sensing Unit (Figure 8)..

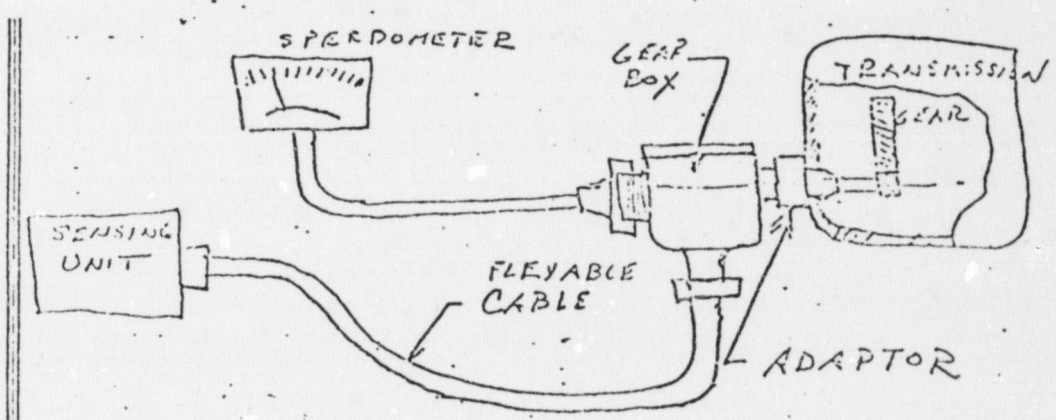


FIG. 8

The gear box (Figure 9) is used to step-up the speed ratio from the transmission in order to gain greater sensitivity in the Sensing Unit. When the rear wheels lock-up, torque is transmitted through the adaptor, gear box and flexible shaft to the Sensing Unit. This action triggers the micro switch in the Sensing Unit as previously described.

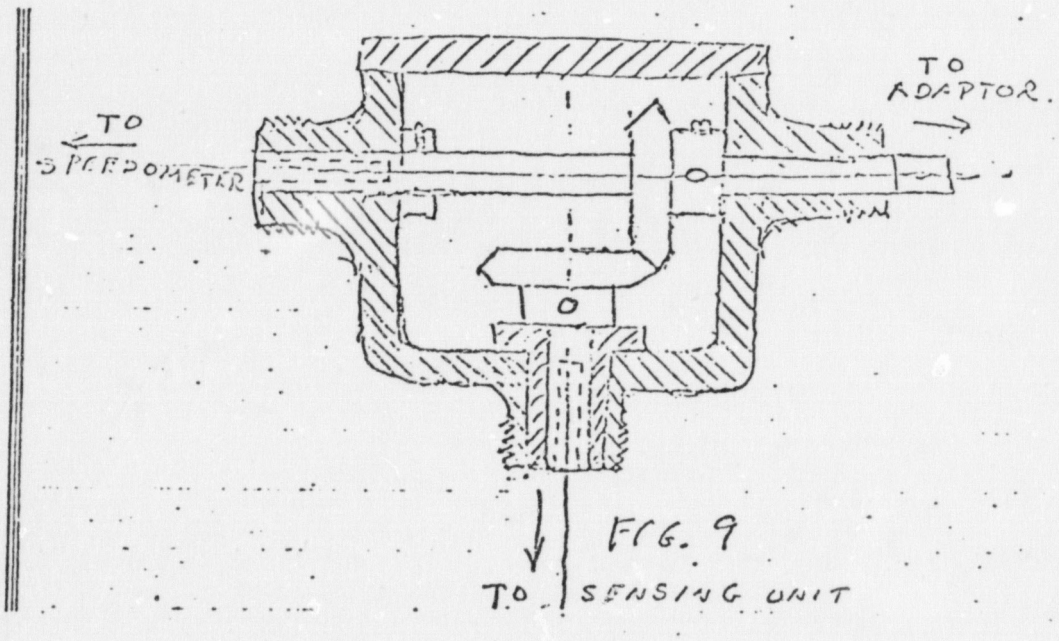


FIG. 9

E. Pressure Switch

The basic function of this assembly is to break the electrical circuit and return the system back to normal braking status after a panic stop. The unit is constructed with a small piston which is spring loaded. The piston moves against the spring force when hydraulic pressure is applied, thereby opening and closing electrical contacts. The switch is pre-set at the factory and should not be re-set in the field. The following is a schematic drawing of the switch.

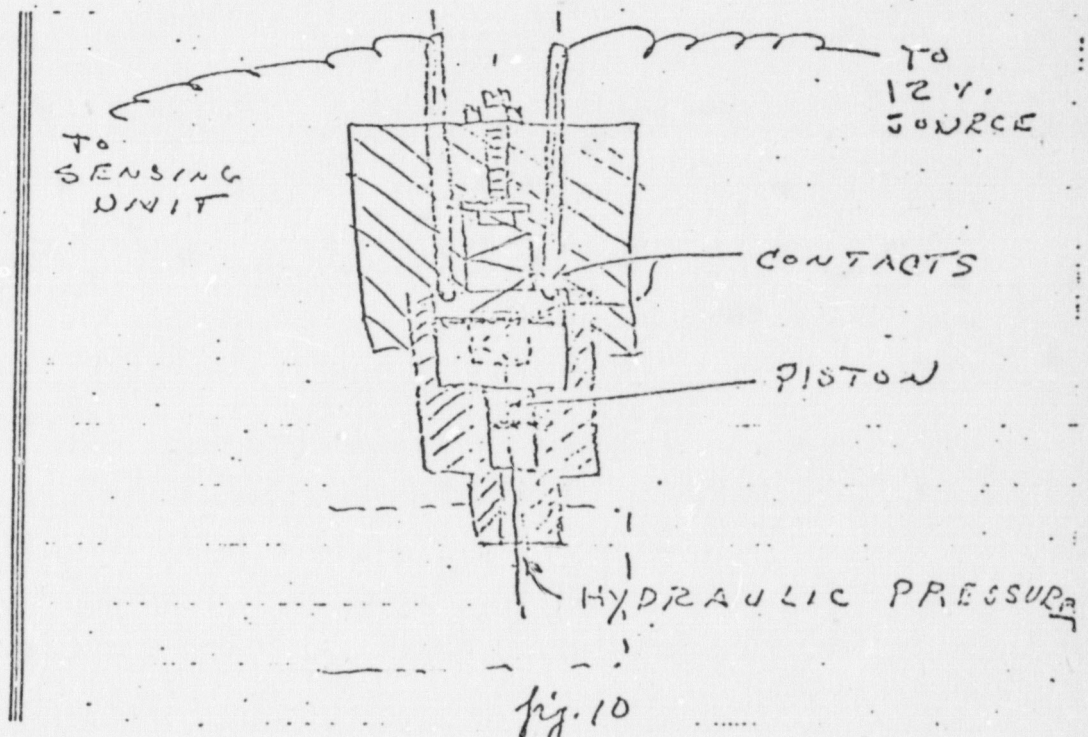


fig. 10

Rick

II. Performance Criteria

A. Operating Range

The unit is designed to cycle within the following ranges when braking is applied abruptly and both rear wheels lock-up.

1. Temperature: 200°F to -30°F (*)

2. Speed:

   a. Maximum: 80 m.p.h. (**)

   b. Minimum: 10 m.p.h.

3. Cycles per second:

   Dry Pavement: 1-2.1

   Wet, Gravel, Snow or Ice: 1.3-2.4

4. Minimum Vacuum: 15 in. Hg. and an excess of 12 cu. ft. per minute in volume of vacuum.

5. Minimum Voltage: 11 Volts D. C.

(**) Vehicles have not been tested over this speed.

(*) This information is based on tests conducted by Perma. Environmental tests at this temperature have not been made by Singer to date.

B. Application Requirements

Vehicles must have:

1. Hydraulic operating drum type brakes.

2. 12 Volt D. C. electrical system.

3. Speedometer take off at transmission.

4. Rear wheel drive.

5. Internal combustion engine which creates a minimum of 15 inches of vacuum and an excess of 12 cu. ft. per minute in volume of vacuum.

6. Vehicle brake system must be in good condition, properly adjusted and bled.

C. Limitations of Unit

1. Steering Control

a. By steering control we mean the operator can maneuver the vehicle during braking when trying to avoid a collision. When stopping the vehicle on two lane roads where straight stopping is essential, the unit enables the operator to stop the vehicle within 0 to 5° with respect to the road.

The unit affords steering control on all road conditions except ice. The unit will not provide steering control under conditions where: steering control would not be available even without brakes being applied due to extremely low road friction; centrifugal skids due to excessive high speeds on sharp curves or high acceleration on slippery roads. These conditions usually occur on wet ice, snow on ice, glazed ice and ice on a crowned road.

b. On mixed road conditions, two right wheels on snow or ice and two left wheels on dry pavement, the unit will enable the operator to bring the vehicle to rest at an angle of 0-5° with respect to the road, depending on the amount of correction introduced by the operator.

2. Stopping Distances with Unit

a. Dry Road Conditions

1. 50 m.p.h. - Increase by .8 to 20%

2. 30 m.p.h. - Increase by 4.4 to 20%

b. Low Coefficient Road Conditions

1. 50 m.p.h. - Decrease by 0 to 10%

2. 30 m.p.h. - Increase by 6 to 15%

3. Ability to Cycle

a. Fooling the unit:

It is possible under certain conditions to lock-up the wheels without cycling the unit. This characteristic is termed "fooling the unit". As stated previously, the brakes must be applied abruptly in order to trip the micro switch in the Sensing Unit. This abrupt braking action is generally applied during emergency stops. However, drivers have been told to apply brakes slowly on slippery road conditions to avoid wheel lock-up. This is practiced by most experienced drivers and therefore they must be informed that the unit will not cycle under these circumstances.

b. Loss of vacuum:

The unit will not cycle if the vehicle stalls or a loss of vacuum to the unit occurs due to hose breakage or excessive leakage in the vacuum system of the unit. If the loss of vacuum occurs before the brakes are applied, during a cycle or prior to reaching the check-off pressure, a loss of braking power will result. The calculated available pressure, disregarding friction is: 450 p.s.i. for a single piston unit, and 485 p.s.i. for a dual unit. This pressure may or may not lock-up the wheels, depending on the speed and condition of the brake linings at the time the failure occurs.

c. Malfunctions due to improper settings, failure of components or breakage of electrical circuits are discussed in detail in Article III (Trouble Shooting and Repair).

d. The unit will function only on those vehicles officially prototyped by Singer. Adapting the unit to vehicles not included on the official list must be discouraged, in that brake systems react differently on each vehicle and design requirements also vary. Under no circumstances is the present design configuration to be used on vehicles equipped with disc type brake systems.

4. Road Test for Cycling

a. Normal Braking

With a vehicle speed of approximately 30 m.p.h., apply gradual braking as is normally done when stopping in traffic or a light. The unit should not cycle when this is done on dry road conditions.

b. Emergency Braking

With a vehicle speed of approximately 30 m.p.h. on dry road conditions, apply the brake abruptly. The unit should cycle in a pattern as shown.

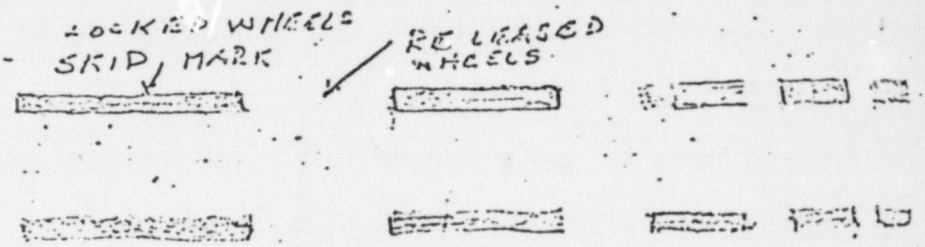


fig. 11

Notice that the length of tire skid marks and the distance between marks diminish as the vehicle speed is reduced. The length of these pulses are a function of road coefficient of friction, tire condition, weight distribution and other variables. Therefore, they will vary between different runs or stops and vehicles.

After the vehicle has come to rest the system should return to normal braking condition. Part (a.) should be repeated to check this feature.

When snow or wet pavement is available the above checks should also be made for these road conditions. Discretion should be used in chosing the test speed.

c. Minimum Cycling Speed

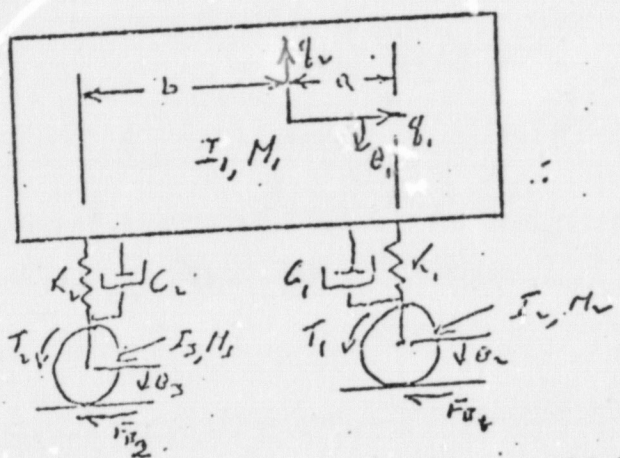
At a speed of 10 m.p.h., apply the brakes abruptly. The unit should cycle. If this is done on dry road conditions, one pulse may only occur and it will be difficult to determine whether or not the unit actually cycled. Therefore, it is suggested that this test be made on gravel when wet road conditions, snow or ice are not available.

< DRIVE GEAR

PLAINTIFF'S EXHIBIT 132

PX ID - 132

VEHICLE EQUATIONS OF MOTION



Equations of motion are derived by the method of LaGrange:

$$\text{Kinetic Energy} = T = \tfrac{1}{2}(M_1 + M_2 + M_3)\,\dot{q}_1^2 + \tfrac{1}{2} M_1 \dot{q}_2^2 + \tfrac{1}{2}(I_1 \dot{\theta}_1^2 + I_2 \dot{\theta}_2^2 + I_3 \dot{\theta}_3^2)$$

$$\text{Potential Energy} = V = \tfrac{1}{2} K_1 (q_2 - a\theta_1)^2 + \tfrac{1}{2} K_2 (q_2 + b\theta_1)^2$$

$$\text{Damping Potential} = D = \tfrac{1}{2} C_1 (\dot{q}_2 - a\dot{\theta}_1)^2 + \tfrac{1}{2} C_2 (\dot{q}_2 + b\dot{\theta}_1)^2$$

Coordinate reference is the equilibrium position; thus gravitational potential energy does not appear.

- Translational kinetic energy is lumped in the q_1 coordinate; thus, the small relative fore and aft motion of the unsprung masses is neglected here. This was justified at a much earlier date by digital computer comparison of both cases.

GENERAL LAGRANGE EQUATIONS OF MOTION ARE:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right) - \frac{\partial T}{\partial q_i} + \frac{\partial V}{\partial q_i} + \frac{\partial D}{\partial \dot{q}_i} = Q_i$$

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}}\right) - \frac{\partial T}{\partial q} + \frac{\partial V}{\partial q} + \frac{\partial D}{\partial \dot{q}} =$$

where Q_1 is generalized force in q_1, coordinate. Therefore we have

$$(M_1 + M_2 + M_3)\ddot{q}_1 = -(F_{B1} + F_{B2}) \qquad \text{Eq. (1);}$$

$$M_1 \ddot{q}_2 + K_1 (q_2 - a\theta_1) + K_2 (q_2 + b\theta_1) + C_1 (\dot{q}_2 - a\dot{\theta}_1) + C_2 (\dot{q}_2 + b\dot{\theta}_1) = 0 \qquad \text{Eq. (2);}$$

$$I_1 \ddot{\theta}_1 + K_2 b (q_2 + b\theta_1) - K_1 a (q_2 - a\theta_1) + C_2 b (\dot{q}_2 + b\dot{\theta}_1)$$

$$-C_1 a (\dot{q}_2 - a\dot{\theta}_1) = \frac{1}{2}(T_1 + T_2) + (F_{B1} + F_{B2})(q_2 + HCG - r) \qquad \text{Eq. (3)}$$

where HCG is static height of M_1 c.g. above ground, and r is wheel rolling radius;

$$I_2 \ddot{\theta}_2 = -T_1 + F_{B1} r \qquad \text{Eq. (4);}$$

$$I_3 \ddot{\theta}_3 = -T_2 + F_{B2} r \qquad \text{Eq. (5)}$$

In the above equations, $F_{Bi} = \mu_i F_i$ where $\mu_i = \mu_i(\eta_i)$ with $\eta_1 = 1 - \frac{r\dot{\theta}_2}{\dot{q}_1}$ and $\eta_2 = 1 - \frac{r\dot{\theta}_3}{\dot{q}_1}$ and F_1 and F_2 are the normal road reaction forces.

PLAINTIFF'S EXHIBIT 133

NUMERICAL CONSTANTS USED IN VEHICLE SIMULATION

Curb weight	4633	lbs.
Front Unsprung Weight	242	lbs.
Rear Unsprung Weight	388	lbs.
CG Location from Center Line of Front Wheel	47.6	inch
CG Location Above Ground	22.2	inch
Pitch Moment of Inertia	2912.	ft lb sec^2
Front Ride Rate	226	lb/in
Rear Ride Rate	246	lb/in
Front damping Jounce	2.58	lb/in/sec
Rebound	6.45	lb/in/sec
Rear Damping Jounce	12.6	lb/in/sec
Rebound	20.	lb/in/sec
Wheelbase	117.2	in
Rolling Radius of wheel	1.152	ft

PLAINTIFF'S EXHIBIT 133A [PX 133 A, p 1]

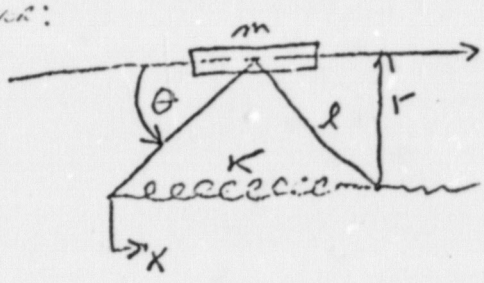
NUMERICAL CONSTANTS USED IN VEHICLE SIMULATION

Curb weight	4633	lbs.	$(M_1 + M_2 + M_3)\ g$
Front Unsprung Weight	242	lbs.	$M_2 g$
Rear Unsprung Weight	388	lbs.	$M_3 g$
CG Location from Center Line of Front Wheel	47.6	inch	a
CG Location Above Ground	22.2	inch	HCG
Pitch Moment of Inertia	2912.	ft lb sec ^{2}	I_1
Front Ride Rate	226	lb/in	K_1
Rear Ride Rate	246	lb/in	K_2
Front damping Jounce	2.58	lb/in/sec	C_1
Rebound	6.45	lb/in/sec	C_1
Rear Damping Jounce	12.6	lb/in/sec	C_2
Rebound	20.	lb/in/sec	C_2
Wheelbase	117.2	in	a + b
Rolling Radius of wheel	1.152	ft	r

PLAINTIFF'S EXHIBIT 134

PERMA EQUATIONS

GOVERNOR:



USE LAGRANGE METHOD:

T = KINETIC ENERGY = $\frac{1}{2} m (r\dot{\phi})^2 + \frac{1}{2} I \dot{\phi}^2 + \frac{1}{2} m (\dot{r}^2 + \dot{s}^2)$

V = POTENTIAL ENERGY = $\frac{1}{2} K (x+\delta)^2$, WHERE δ IS SPRING COMPRESSION AT $x=0$, $\theta=\theta_0$.

NOW $x = 2l(\cos\theta_0 - \cos\theta)$, $r = l\sin\theta$, $s = \frac{x}{2}$

$\therefore \cos\theta = \cos\theta_0 - \frac{x}{2l}$ AND $\sin^2\theta = 1 - \cos^2\theta$

$= 1 - \left(\cos\theta_0 - \frac{x}{2l}\right)^2$.

USING THESE RELATIONS WE ARE ABLE TO REDUCE T TO A FUNCTION OF $x, \dot{x}, \dot{\phi}$:

THUS, $$T = \frac{1}{2}\left\{ I + ml^2\left[1 - \left(\cos\theta_0 - \frac{x}{2l}\right)^2\right]\right\}\dot{\phi}^2 + \frac{1}{2} m \left\{ \frac{\dot{x}^2\left(\cos\theta_0 - \frac{x}{2l}\right)^2}{4\left[1 - \left(\cos\theta_0 - \frac{x}{2l}\right)^2\right]} + \frac{\dot{x}^2}{4} \right\}$$

THE GENERAL LAGRANGE EQUATIONS OF MOTION ARE: $$\frac{d}{dt}\left[\frac{\partial (T-V)}{\partial \dot{q}_i}\right] - \frac{\partial (T-V)}{\partial q_i} = Q_i$$

FOR US $q_1 = x$, $Q_1 = 0$

$q_2 = \phi$, $Q_2 = M$ = TORQUE APPLIED

$\therefore$ FOR x WE GET

ENTIRE

$$m\ddot{x} - \frac{m\dot{x}^2}{2\ell}\frac{\cos\theta_0 - \frac{x}{2\ell}}{1-\left(\cos\theta_0 - \frac{x}{2\ell}\right)^2} - \left[\frac{1}{2}m\ell\dot{\phi}^2\left(\cos\theta_0 - \frac{x}{2\ell}\right) - K(x+\delta)\right]\left[1-\left(\cos\theta_0 - \frac{x}{2\ell}\right)^2\right] = 0$$

NOW LET $\frac{x}{x_{max}} = \bar{x}$; THEN $\ddot{x} = x_{max}\ddot{\bar{x}}$)

$\ddot{x} = x_{max}\ddot{\bar{x}}$. ALSO LET $\omega_n^2 = \frac{K}{m}$.

$$\therefore x_{max}\ddot{\bar{x}} - \frac{x_{max}^2\dot{\bar{x}}^2}{2\ell}\frac{\cos\theta_0 - \frac{x_{max}\bar{x}}{2\ell}}{1-\left(\cos\theta_0 - \frac{x_{max}\bar{x}}{2\ell}\right)^2}$$

$$- \left[\frac{1}{2}\ell\dot{\phi}^2\left(\cos\theta_0 - \frac{x_{max}\bar{x}}{2\ell}\right) - \omega_n^2\left(x_{max}\bar{x} + x_{max}\bar{\delta}\right)\right]\left[1 - \left(\cos\theta_0 - \frac{x_{max}\bar{x}}{2\ell}\right)^2\right] = 0$$

NOW LET $l_R = \frac{x_{max}}{\ell}$

THEN $$\ddot{\bar{x}} - \frac{\dot{\bar{x}}^2}{2}\frac{l_R^2\left(\frac{\cos\theta_0}{l_R} - \frac{\bar{x}}{2}\right)}{1 - l_R^2\left(\frac{\cos\theta_0}{l_R} - \frac{\bar{x}}{2}\right)^2} - \left[\frac{\dot{\phi}^2}{2}\left(\frac{\cos\theta_0}{l_R} - \frac{\bar{x}}{2}\right) - \omega_n^2\left(\bar{x} + \bar{\delta}\right)\right]\left[1 - l_R^2\left(\frac{\cos\theta_0}{l_R} - \frac{\bar{x}}{2}\right)^2\right] = 0$$

FOR THE STEADY STATE,

$$\frac{1}{2}\dot{\phi}^2\left(\frac{\cos\theta_0}{k_R} - \frac{\bar{x}}{2}\right) = \omega_n^2(\bar{x}+\bar{\delta})$$

HENCE $$\bar{x} = \frac{\frac{K_R^2}{2}\frac{\cos\theta_0}{k_R}\left(\frac{\omega}{\omega_n}\right)^2 - \bar{\delta}}{1 + \frac{K_R^2}{4}\left(\frac{\omega}{\omega_n}\right)^2}$$

WHERE $\dot{\phi} = K_R\omega$; ω IS WHEEL SPEED AND K_R IS THE NET GEAR RATIO OF SENSOR SPEED VS WHEEL SPEED.

$$\therefore\ \bar{\delta} = \frac{K_R^2}{2}\frac{\cos\theta_0}{k_R}\left(\frac{\omega_{low}}{\omega_n}\right)^2 \quad \text{FOR } \bar{x}=0.$$

AND $$\frac{\cos\theta_0}{k_R} = \gamma = \frac{1 + \frac{K_R^2}{4}\left(\frac{\omega_{low}}{\omega_n}\right)^2}{\frac{K_R^2}{2}\left[\left(\frac{\omega_{low}}{\omega_n}\right)^2 - \left(\frac{\omega_{low}}{\omega_m}\right)^2\right]}$$

WHERE ω_m AND ω_{low} ARE THE WHEEL SPEEDS FOR BRAKES FULL ON AND FULL OFF RESPECTIVELY.

HENCE $\gamma = \frac{\cos\theta_0}{k_R}$ IS CONSTANT. ALSO, SINCE $2k_R\cos\theta_0 \geq K_{max}$,

$\gamma \geq \frac{1}{2}$.

FOR A GIVEN γ, k_R CAN BE MADE ARBITRARILY SMALL SUCH THAT k_R^2 IS NEGLIGIBLE. THEN OUR EQUATION OF MOTION REDUCES TO

$$\ddot{\bar{x}} + \left(K_R^2\omega^2 + 4\omega_n^2\right)\bar{x} = 2K_R^2\omega^2\gamma - \omega_n^2\bar{\delta}$$

SINCE THIS IS A LINEAR DIFFERENTIAL EQUATION, IT OBEYS

SEEN THAT THE SENSOR RESPONSE CAN BE MADE ARBITRARILY FAST FOR ANY WHEEL SPEED BY MAKING ω_n LARGE (i.e. STIFF SPRING RELATIVE TO FLYING WEIGHTS)

THE REMAINING LAGRANGE EQUATION IS

$$\frac{d}{dt}\left[\frac{\partial(T-V)}{\partial \dot{\phi}}\right] - \frac{\partial(T-V)}{\partial \phi} = M(t)$$

HENCE $\left\{I + ml^2\left[1 - \left(\cos\theta - \frac{x}{2\theta}\right)^2\right]\right\}\ddot{\phi} + ml\dot{\phi}\dot{x}\left(\cos\theta - \frac{x}{2\theta}\right) = M(t)$.

SINCE $\dot{\phi}$, $\ddot{\phi}$ ARE INPUTS TO THE GOVERNOR FROM THE WHEELS, THIS IS SIMPLY AN EXPRESSION FOR THE TORQUE ON THE GOVERNOR SHAFT.

ENTERED

SOLENOID: $\tau_{SOL}\dot{x}_{SOL} + x_{SOL} = x_{INPUT}$

DECELERATION SENSOR: $\tau_{DEL}\dot{\alpha} + \alpha = \alpha_{INPUT}$

BRAKE TORQUE COMBINED WITH PERMA-VAC: $\tau_{VALVE}\dot{T} + T = T_{DEMAND}$

PLAINTIFF'S EXHIBIT 135

Numerical Constants in the Simulation of the Perma Anti-Skid Device

1. Speed at which governor weights fully extended — 12 mph

   Source: Singer Document entitled "Anti-Skid Control", dated May 7, 1965, (D.P.E. No. 456)

2. Spring Rate in Sensing Unit

Distance	1.380-1.395
Load	23 oz

   Source: Drawing 105B

3. Length of governor weight link — 0.53 inches

   Source: Drawing 104B

4. Governor Weight

Density	0.745
Height	0.305
Middle hole	0.186

   Source: Drawing 103B

5. Angle of Weight and link — 45°

   Source: Drawing 146

6. Threshold of Cam Gear

Operating threshold	0.92 g's
Time of operation	20 millisec

   Source: Drawing 101E

7.	Solonoid Operating time Source: Past experience with similar devices	30 millisec
8.	Movement of Rotary Valve Source: Measurements from hardware	0.25 inches
9.	Activator Response time Source: Past experience with similar devices	30 millisec
10.	Pressure Switch Settings Source: Computed from settings in D166 modified to reflect differences between 1964 and 1968 vehicles	115-159 psi

PLAINTIFF'S EXHIBIT 136

680137

The General Motors Proving Ground Model II Coefficient of Friction vehicle is capable of measuring slipping as well as sliding tire-road braking friction properties. The design, system capabilities, operating features, translucing elements and data processing instrumentation are discussed along with the techniques used to verify system performance; typical percent slip versus brake torque coefficient data on various surfaces and conditions are included. Conclusions are drawn on the relative usefulness of a torque measuring device for measuring tire and/or road braking friction properties as a result of tire patch point relocation studies.

Tire-Road Friction Measuring System — A Second Generation

Gary L. Goodenow, Thomas R. Kolhoff, and Fraser D. Smithson
Proving Ground Section, General Motors Corp.

THE MODEL I Friction Test Trailer built by the General Motors Proving Ground in 1953 was a device capable of obtaining test data for sliding coefficients of friction between a tire and road surface; measurements that could be made with reference tires or on reference road surfaces. Its capability, although limited, was adequate for its intended purpose.

With increasing interest in tire-road interface phenomena, it was necessary for the Proving Ground to have a research device which could be used to further these studies.

Interest in tire-road coefficient measurement by many organizations had prompted the American Society for Testing and Materials to strive for some unification in this field. Thus, the ASTM E-17 Committee on Skid Resistance has written tentative specifications on the design aspects of 2-wheel trailers for skid resistance measurement (1)*, specifications to be included in the development of a new Proving Ground system.

OBJECTIVES

Specifically, the operational objectives were as follows:

1. Comply with all requirements as set forth by the ASTM E-17 Committee.
2. Be capable of measuring and defining tire-road coefficients under the following conditions:
   a. Dry road or, wetted to 0.020 ± 0.005 in. film thickness, at all speeds.
   b. Measuring data with left tire, right tire, or both tires.
   c. Operating speed range compatible with present driving speeds.
   d. Handle all present passenger car tire sizes.
   e. Variable normal axle loads compatible with average passenger car loads.
3. Provide complete operator control, monitoring and data readout in the cab of the towing vehicle.
4. Provide data of convenient form for evaluating coefficient of friction at different percentages of slip for the tire(s) under test.
5. Require a minimal expenditure of time and money for maintenance and repair.
6. Include accessories for optimizing operating time when used as a data gathering device.
7. Provide maximum flexibility for modification as future research dictates.

BASIC SYSTEM

The GMPG Model II Coefficient of Friction Vehicle consists of a specially fabricated trailer towed by a modified 1967 Chevrolet pickup truck (Fig. 1). The tow truck serves as a control and data readout center.

With this system, skid resistance measurement is accomplished by braking a trailer tire(s) at a constant vehicle speed and recording various parameters which are used to compute the final output μ, or braking coefficient. The commonly accepted value of this tire-road braking coefficient, as measured with a towed, 2-wheel vehicle, is calculated using the formula:

$$\mu = \frac{F_f}{W_s - \frac{h}{lw} F_f} \qquad (1)$$

* Numbers in parentheses designate References at end of paper.

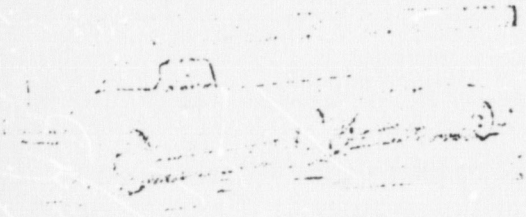


Fig. 1 - GMPG Model II friction test vehicle

where:

F_f = Friction force at the tire-road interface.
W_s = Static weight on the test wheel.
h = Trailer hitch height.
l_w = Distance between trailer hitch and axle.

Thus, to define the braking coefficient requires measuring or computing from measurements, the friction force at the tire-road interface and establishing the other parameters used in the equation.

The friction force term with the Model II system is defined as the torque generated on the axle assembly during braking, divided by the rolling radius of the tire.

$$F_f = \frac{T}{R_R} \qquad (2)$$

where:

F_f = Friction force at the tire-road interface.
T = Measured brake torque.
R_R = Tire rolling radius.

This equation assumes that there is no torque component due to tire patch center of pressure relocation and that the tire rolling radius does not vary significantly during the braking cycle.

The coefficient established is unique to the particular operating conditions; these include the tire used, the surface on which the test was made, the speed of the vehicle at the time the measurement was made and the angular velocity of the tires. For much of the testing, the angular velocity condition is zero because the sliding coefficient is being measured. However, as a research device, it would be important to be able to determine the braking coefficient at incipient conditions during braking. In this case, the coefficient is [illegible] as a function of the percent slip of the test [illegible] and vehicle [illegible] in the [illegible] with friction [illegible]

SYSTEM CAPABILITY

The system has been designed so that the various modes of operation (with the exception of axle normal load and the actual mounting of the test tire) are selected by the operator at the control console in the cab of the truck. The system concept provides the operator with maximum flexibility by allowing him to combine the various modes to best meet the requirements. A description of the available modes and some of the possible combinations are:

1. The truck and trailer are capable of operating at test speeds of 0-100 mph, depending on the road surfaces available and the test requirements.

2. A built-in water supply and surface wetting system provides for either wet or dry surface testing, individually controlled for each wheel.

3. Individual brake systems for each trailer wheel allow either or both wheels to be locked. The separate brake and water systems permit selective individual combinations of braking and wetting.

a. Fast lockups - (less than 0.5 sec) are available for data gathering of sliding coefficients.

b. Regulated lockup - (up to 10 sec total braking time) is provided to more fully evaluate coefficients during the braking cycle, before lockup.

4. To avoid excessive tire wear, an automatic brake release after lockup is selectable for either wheel.

5. Wheel adapters allow the mounting of any tire and wheel assembly presently used on General Motors Corp. passenger cars.

6. Trailer axle normal load can be varied from 750-1400 lb/wheel with individually located 50 lb weights. Additional ballast may be added to achieve test weights up to 1500 lb. If extremely light loads are required, the weight may be lowered to approximately 500 lb/tire by removing bolt-on components such as the cover, jacks, etc.

7. An 8-channel direct writing recorder provides immediate and permanent records of all data.

Built-in data processing and analog computing circuits allow the output of the various transducers to be used for the following data records:

1. A record of trailer drawbar load.

2. A record of true vehicle speed and distance traveled in feet from the built-in fifth wheel precision speedometer and electronic revolution pulser.

3. A record of each trailer wheel angular speed.

4. A record of the percent slip of the test wheel speed compared to the reference wheel speed.

5. A record of the total torque from each trailer wheel torque transducer.

6. A record of the corrected brake torque at points between free rolling and locked wheel skid conditions. The corrected torque of the wheel being tested is computed by subtracting the torque due to the product of wheel [illegible] and [illegible] from the total torque measured by the brake torque transducers.

[illegible] both of these values, selected [illegible]

TRACTION MEASURING SYSTEM

forces, are recorded, they can be compared to obtain a plot of coefficient versus percent slip. This is valuable in evaluating the behavior of the tire and road surface at incipient skid conditions.

CONTROL AND OPERATING SYSTEMS

The modes of operation are controlled by an electro-pneumatic-hydraulic control system. Electronics, pneumatics and hydraulics are combined to achieve a unified system where each is performing related but individual operations.

ELECTRONICS - The electronic portion of the control circuit is used to command the operation of the pneumatic and hydraulic systems and to condition and record the necessary information for data presentation. The truck 12 V d-c electrical system is used as the primary electrical source. This is used to power the 110 V, 60 cycle power supply, and the d-c switching and relay circuits for the solenoid valves. The 110 V a-c system is used to power the direct writing oscillograph, digital voltmeter, and four regulated d-c power supplies. The regulated d-c voltages power the strain gage bridge circuits and solid-state electronic modules (that is, amplifiers, dividers, etc.).

PNEUMATICS - Pneumatic power is developed by an air compressor on the truck. After proper preparation and regulation, this air is used as a control media for the air-hydraulic converter and as a power source for controlling several auxiliary pneumatic devices.

HYDRAULICS - The regulated hydraulic power from the air-hydraulic converter is used to apply the trailer brakes in accordance with the preselected test mode. Hydraulic power is also used to operate the trailer jacks.

SYSTEM OPERATION - The most important part of the vehicle is the braking system. The block diagram (Fig. 2), will be used to discuss it. The operator first selects whether the air supply will be maximum or variable flow regulated. He also selects whether the time-delay dropout relays will be used or not (their effect will be discussed later). The arming switches determine which of the normally open brake valves will close when the command button is pushed. Upon energizing the command button, the air passes through the air solenoid to the air-hydraulic converter. Oil from the converter applies the brakes on either side which has an open brake valve. If the time delay dropout relay is used, the normally open valve controlling the selected test brake(s) closes when the air-hydraulic converter starts. After hydraulic pressure builds up to the valve, the relay opens the valve and provides a very high rate backup of the test brake. Since the entire hydraulic portion of the braking circuit is normally open, a normal air valve can be used to supply air pressure to the air-hydraulic converter and apply the trailer brakes. This provides emergency trailer braking independent of the electrical system.

Dive brakes were selected to eliminate the self-energizing action of a conventional drum brake system and to obtain a linear relation between brake fluid pressure and braking force. The trailer braking control system is of an

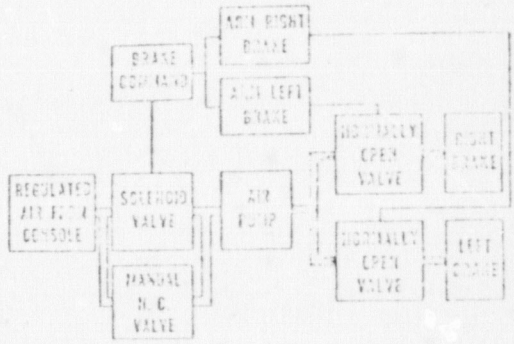


Fig. 2 - Basic braking circuit

Fig. 3 - Truck interior and operating console

open loop nature, thus a single cycle between 0 and 100% slip, constitutes one individual test. The time rate of this single cycle can be varied, but no attempt is made to hold the percent slip at a fixed value, or to recycle within the range of 0-100% slip.

The operating console is shown in Fig. 3. At the top of the sloped section is the digital voltmeter used to monitor the various functions of the electrical and electronic circuits. The five lighted switches on the sloped section control the switching of the power supplies, trailer jack cranks, fifth wheel pickup, and indicate sufficient air pressure. The forward row of five switches on the flat section are the command switches for the chart drive, water, brakes, and automatic brake release. The 10 turn pots and switches below them are used for scaling and torque correction. The section at the left rear is used for the strain gage bridges. It includes regulation of bridge current, balance, and calibration.

The valving on the left side of the console, beginning at the bottom, variable orifice regulator, regulated pressure selector, and the manual brake valve. The face of the 8-channel direct writing oscillograph can be seen at the top of the photo.

One rather unique feature of the control system is the

[illegible] sequencing controller. A series of adjustable time-delay relays provide automatic control, after proper arming, of the bucket emitter, water, braking, and brake release. This is executed either by a button on the console or a hand held remote cable.

Modular construction has been used on the entire control system for ease of repair, maintenance, and adjustment. The entire console can be lifted out of the chassis. The electric power supplies are mounted behind the driver's seat and the air preparation system is located behind the passenger seat. Switching relays, trailer control devices, and all pneumatic and hydraulic controls are mounted under sealed covers on the trailer.

MECHANICAL DESIGN FEATURES

TRUCK - The truck accessories include such things as heavy duty suspension, air conditioning, power steering and brakes, automatic transmission and bucket seats. A 325 hp engine was installed to meet the high speed requirements. The interior of the vehicle was modified to accept the operating console. The rear bumper was changed to provide a low hitch point height and a convenient interface between the truck and trailer. A power takeoff unit in the drive train drives a fixed displacement water pump. This provides a water flow volume proportional to vehicle speed. The water supply is carried in a 230 gal baffled water tank located in the bed.

TRAILER - The trailer is a specially built unit incorporating a perimeter type frame and a passenger car, 4-trailing arm, coil spring suspension (Fig. 4). The use of a coil spring suspension eliminates low frequency resonance on the torque data, which is experienced when using leaf springs in a friction test trailer. The entire trailer is covered with a one-piece, molded fiberglass shell which provides component protection and lowers wind drag-force. The water nozzles located on the trailer direct a uniform water film ahead of the test tire(s) independent of test speed. If only one trailer water valve is opened, the water film depth ahead of the test wheel is approximately 0.040 in. If both water valves are opened, a 0.020 in. film is provided ahead of each trailer tire. The ASTM specification for water film thickness, to use in wet testing, is 0.020 ± 0.005 in. By using a correctly sized pump, the Model II system meets this specification when watering both test wheels. Verification was performed by analysis of high speed movies and mass flow versus time tests.

ACCESSORIES - Several operating accessories have been built into the trailer to augment its operation and flexibility. Since many data gathering operations involve frequent tire changes, the trailer has been equipped with hydraulic lift jacks and an air operated torque wrench. The wheel adaptors can be used with a single or a type locking nut if short test sequences are involved. The fifth wheel can be remotely raised and lowered from the cab with a pneumatic cylinder. The weights used to change the normal load are individually located and retained in place with safety cables.

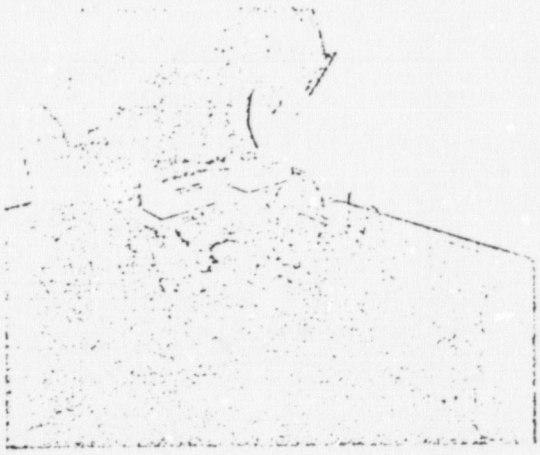


Fig. 4 - Interior view of Model II trailer

TRANSDUCERS

Four types of transducers are used in the system. These are used to measure total wheel brake torque, drawbar load, individual trailer axle shaft angular velocity, and true vehicle speed.

WHEEL TORQUE TRANSDUCERS - A wheel torque transducer is shown in Fig. 5. This is a tube of uniform cross-section with stiff end members to terminate the tube section. The rear flange is attached to the axle tube and the disc brake caliper is bolted to the front flange. All of the load exerted by the calipers on the brake rotor must be reacted through the tube section to the axle housing. The uniform tube section is strain-gaged to measure torsional shear strain only, and has less than 1% sensitivity to any expected cross-axis loading. Since the gaged surface is at a fixed distance from the axle centerline, torsional shear strain is directly related to torque about the transducer.

DRAWBAR FORCE - Trailer drawbar load, which can be used in the calibration process, is measured with a conventional tensile beam incorporating a 4-arm, strain-gaged bridge. Since this drawbar transducer will not withstand the vertical trailer tongue loads, but must measure all of the axial loads, it is integrally mounted with linear bushings in the tongue.

TRAILER AXLE, ROTATIONAL VELOCITY - The transducers used to determine the individual angular velocity of each trailer wheel are photoelectric pulse generators (360 pulse/rev.) mounted in the modified axle housing of the trailer. These provide a sinusoidal voltage output, the frequency of which is directly proportional to the rotational velocity of the axle shaft.

FIFTH WHEEL - The transducer used to measure true vehicle speed is a fifth wheel precision speedometer mounted behind the axle in the centerline of the trailer. This fifth wheel provides two outputs: a d-c voltage proportional to

THE ROAD FRICTION MEASURING SYSTEM

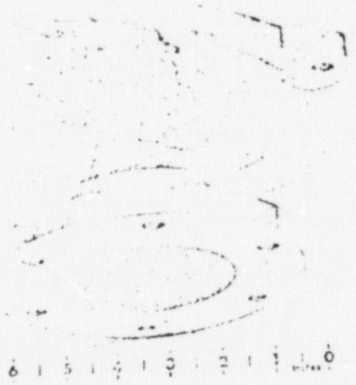


Fig. 5 - Wheel torque transducer

the speed of the vehicle and a pulse signal - 1 pulse for every 1 ft distance traveled.

DATA PROCESSING INSTRUMENTATION

The data processing section of the system contains the signal conditioning, computing and recording components. The various data outputs are as follows:

1. Total wheel torque - (left and right) - this analog information is recorded on the direct writing oscillograph as the total wheel torque transducer output. Used primarily for evaluating sliding coefficients.

2. Angular traffic wheel speed (left and right) - This is recorded as an analog d-c voltage proportional to rotational wheel speed.

3. Drawbar load - An analog d-c voltage proportional to drawbar load.

4. True vehicle speed - An analog d-c voltage which is calibrated to represent vehicle speed.

5. Distance traveled - A digital signal recorded, where each pulse represents 1 ft of distance traveled.

6. Percent slip - This is an analog d-c voltage proportional to the percent slip of the test tire. Percent slip is defined by the following equation:

$$\text{Percent slip} = \frac{W_r - W_t}{W_r} \times 100\% \qquad (3)$$

where:

W_r = Rotational speed of reference wheel.

W_t = Rotational speed of test wheel.

This quantity can only be recorded when one wheel braking is used. Switches on the console are used to select the braked wheel as the reference wheel. The d-c voltages representing individual wheel speeds are then summed in a difference amplifier to obtain the numerator of the equation. Dividing this quantity by the d-c voltage representing the reference wheel speed results in the final output, percent slip. Dependent on the scaling, the recording output of the percent slip circuit represents a fixed d-c voltage, independent of speed. After the test wheel is sliding, the output is zero. Knowing only the maximum and minimum galvo trace deflection, the percent slip can be read at any point during the braking cycle.

7. Corrected wheel torque - Corrected torque is defined by the equation:

$$T_c = T_t - I\alpha \qquad (4)$$

where:

T_c = Corrected torque.

T_t = Total wheel torque.

I = Polar moment of inertia of the rotating test wheel and assembly.

α = Angular deceleration of the test wheel.

Corrected wheel torque for either wheel (one at a time) can be recorded on the oscillograph. An analog computation circuit provides this analog d-c voltage in the following manner:

a. Total wheel torque is scaled in a fixed voltage to in.-lb relationship.

b. The analog voltage representing rotational speed of the test wheel is differentiated to obtain an analog d-c voltage representing rotational deceleration of the test wheel. This voltage is then divided by a potentiometer which represents $1/I$. The resultant voltage represents the inertial correction quantity $I\alpha$. This is scaled to the same V/in.-lb scaling as total wheel torque.

c. Summing (a) and (b) above in a difference amplifier, the resultant analog voltage represents corrected wheel torque. This is then recorded on the direct writing oscillograph.

The use of mechanical zero adjustments on the recorder galvos, and switches on the console allows the operator to select which of the available data traces will be recorded. Thus, only those data which are of interest in a given test cycle are on the chart paper. Data trace separation time is therefore minimized.

SYSTEM VERIFICATION - After completing the Model II system, extensive checks were made to assure that the system complied to design specifications. These checks were of the wheelspeed transducers, signal conditioning, computer, and recorder systems, since earlier experience had shown the torque transducers to be excellent. Frequency response measurements on the signal conditioning circuits and recorder, to check for accurate wave form reproduction fidelity, response, and amplitude, indicated that response was

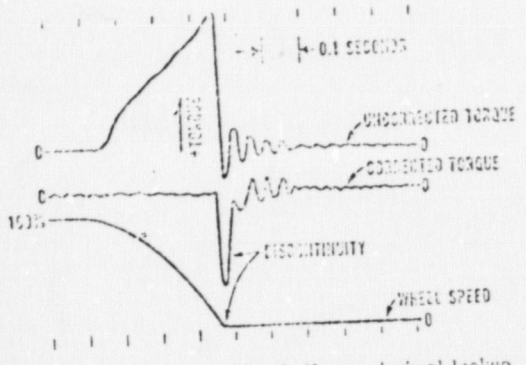


Fig. 6 - Raw oscillogram of off-ground wheel lockup

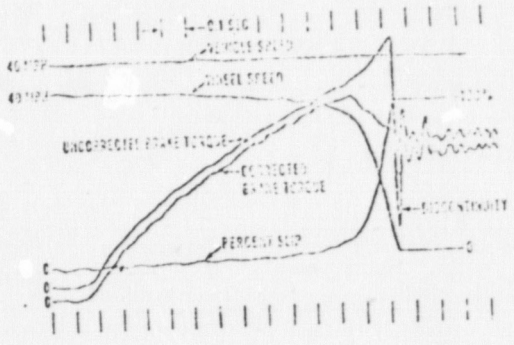


Fig. 7 - Typical oscillograph test record

only limited by the light beam galvanometer selected for the particular data channel.

A complex and unique feature of the Model II system is its inertia torque correction circuitry; particular care was taken to assure proper functioning of these circuits. Bench tests had been performed with artificial inputs but tests were needed to encompass the entire system.

When a tire and wheel are braked while operating off the ground, all the brake torque produced is due to inertia of the tire, wheel, and brake rotor. If the computer circuit functions properly, when correctly scaled, there should be no torque output from a test of this type. Since the torque transducers are strain-gaged with two separate bridges per transducer, it is possible to simultaneously record both direct and inertia-corrected brake torque. Fig. 6 shows a raw oscillogram for an off-ground lockup. Corrected and uncorrected brake torque and wheel speed traces are shown. The uncorrected torque trace has a peak torque of approximately 5000 in.-lb. The corrected torque trace indicates zero torque up to a point just short of complete lockup. The surge or discontinuity on the trace at this point is created by the change in wheel speed from some small value to zero. This change is seen by the differentiator as a rapid acceleration of the wheel, producing a corresponding torque pulse. The trace quickly returns to the normal oscillation created by the torsional vibration of the tire and wheel mass after the rapid off-ground lockup. The acceleration discontinuity is ignored and does not hinder data acquisition since it occurs at such a high percent slip.

The off-ground lockup technique confirms that the computer is providing accurate inertia torque correction and that computer scaling is correct. Tri-filar pendulum test inertia values for tire and wheel assemblies can be dialed in directly and give proper inertia correction.

While tests as previously described give confidence in test results, correlation with other devices is essential. In November 1967, General Motors Proving Ground participated in the ASTM-sponsored Skid Trailer Correlation study hosted by the Florida State Road Dept. Analysis of these data has not been completed and reported by Florida, however, our examination of these data indicate the Model II system correlated with the other units in attendance in terms of sliding brake torque coefficients.

TEST DATA - Since completion of the Model II system, some brake torque coefficient versus percent slip data have been generated. Fig. 7 is a typical oscillograph record of actual road data. This record again shows two torque traces from the test wheel, uncorrected and corrected. Vehicle speed, wheel speed, and percent slip have also been recorded. The peak torque occurred at a relatively low percent slip and falls to the sliding or 100% slip value. The acceleration discontinuity previously described can be seen on the corrected torque trace and it occurred at about 90% slip.

The records are reduced by reading torque deflections at fixed percent slips and reduced to coefficients either by hand or by means of a digital computer program. A minimum of five runs at a given test condition are averaged to provide the final data. When reduced by means of the computer, each set of data is analyzed for statistical variance to provide confidence limits.

Figs. 8-12 are reduced data for the same tire operating on various road surfaces at different speeds. These data are not meant to imply any particular significance relative to any given surface's performance, since they are based on tests at one point in time on one particular sample of that particular pavement or surface.

Figs. 8 and 9 are data for wet and dry asphalt at 30, 40, and 60 mph. In the case of wet asphalt, it can be seen that the sliding or 100% slip coefficient is decreasing with speed and in each case, the peak coefficient is at a relatively low percent slip and of higher magnitude. The ratio of peak to sliding coefficient, as listed, shows a tendency to increase with speed indicating that the peak coefficient is not decreasing with speed at the same rate as the sliding coefficient.

The dry asphalt data show a remarkable change in performance as compared to the wet asphalt data. In this case, there is no appreciable change in the sliding coefficient with speed; however, the peak coefficient is decreasing such that, at 60 mph, it is not appreciably greater than the sliding value.

Figs. 10 and 11 give similar data on wet and dry portland concrete. While coefficients are of different magnitudes,

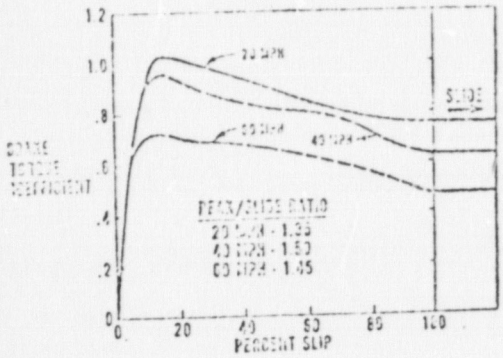


Fig. 8 - Typical brake torque coefficient curves for wet asphalt

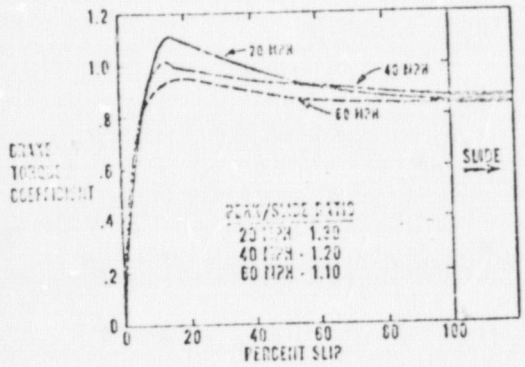


Fig. 9 - Typical brake torque coefficient curves for dry asphalt

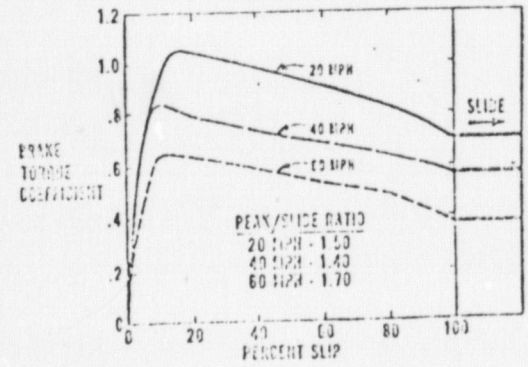


Fig. 10 - Typical brake torque coefficient curves for wet portland cement

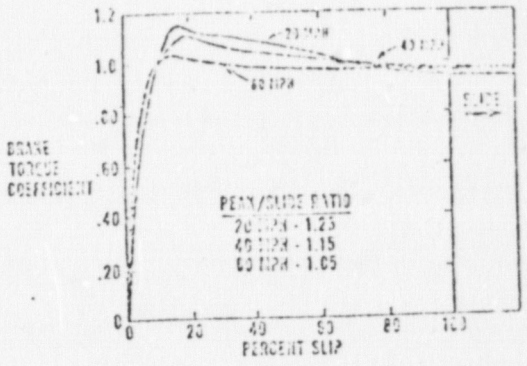


Fig. 11 - Typical brake torque coefficient curves for dry portland cement

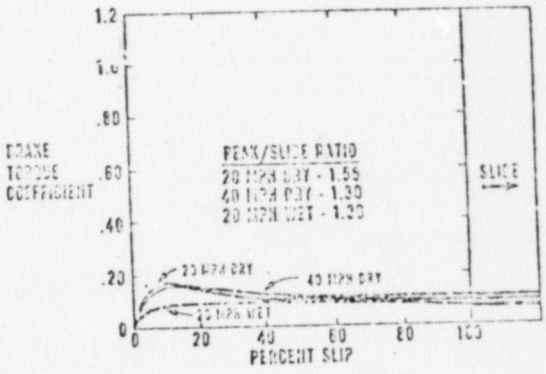


Fig. 12 - Typical brake torque coefficient curves for ice

the dry coefficients are very high on this particular test section. The comments made for wet and dry asphalt still apply.

Fig. 12 shows data taken on glare ice. Ice temperature was about 20 F. Data are shown for 20 and 40 mph dry ice and 20 mph wetted ice. The data indicate that dry ice behaves to some extent as did the dry pavement in that the peak to sliding ratio is decreasing with speed while the peak at 40 mph is moving to a higher percent slip. The 20 mph wet ice trace shows a peak to sliding ratio, the same as 40 mph dry ice but the peak is very broad and at a relatively high percent slip. However, while some peak value is available, the overall magnitudes are all very low.

It should be noted that the data shown as well as all data taken with the Model II system represent a single pass open loop measurements namely, no attempt has been made to maintain any given percent slip nor traverse the vicinity of the curve in a reverse direction. Any explanation of the effect

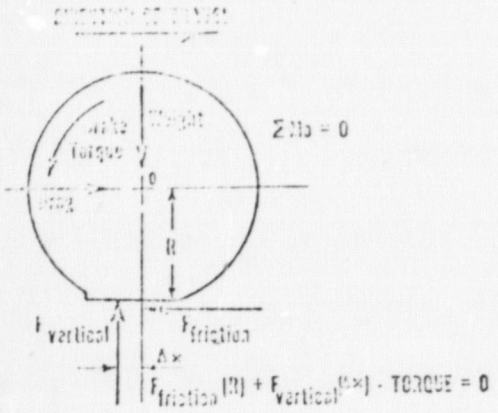


Fig. 13 - Free body diagram of braked tire

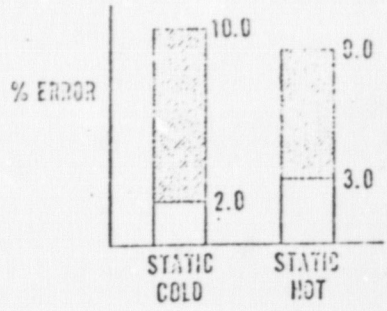


Fig. 14 - Measurement error percentages for hot and cold static tire tests

these sections have on coefficient slip data would be merely conjecture.

It is interesting to note the relative values of the peak and sliding coefficient and the ratio of these coefficients. Theoretically, any design of an antiskid brake system can only decrease vehicle stopping distance as related to this ratio or, conversely, this ratio indicates the degree of improvement in stopping distance that may be achieved as related to a locked wheel stop. It has become apparent that peak and sliding coefficients are both necessary to properly describe tire-road properties.

The relative shapes of the coefficient slip curves are also interesting in that the peak usually occurs at a relatively low percent slip, when this is true, the shape of the slip coefficient curve from 40-100% slip may not be a totally accurate description. The time required to traverse this region even with a slow lockup is very short and phase relationship error in either the wheel speed or torque data could generate some error in this curve. Small phase shift errors could be created by differences in amplifier or recorder galvanometer characteristics.

Particular pains have been taken to emphasize the terms "brake torque" and "brake torque coefficient" when referring to data produced by the Model II system. As stated earlier in this paper, one of the initial design objectives was to measure tire friction forces.

The majority of friction test trailers or skid trailers define friction force as wheel torque divided by the tire static radius. Examination of the free body diagram (Fig. 13) shows that this technique requires two assumptions. First, the tire radius when rolling at speed is the same as a static measured radius. Second, tire patch center of pressure relocation is either negligible or equal in all tires.

The first assumption appears to be feasible. Changes in radius under static loading conditions are of a negligible magnitude. While this does not confirm a lack of dynamic error, the second assumption would appear to be of greater significance.

Patch point relocation defined as distance ΔX in Fig. 13 would create an additive torque couple as per the given summation of moments. While this phenomenon has been discussed (2) in the literature, no magnitudes have been placed on this relocation as related to particular tire types or tire pressure. Therefore, tests were conducted to define the effect of this phenomenon.

Static measurements were made of all components of the free body diagram and actual displacements and percent errors were calculated. Tests were performed on many different tire makes and types over a range of tire pressures. These were tested at room temperature and immediately after warm-up on a vehicle. The test data in all cases showed a linear relationship of patch point displacement relative to fore and aft or friction force up to equivalent coefficients above one. Therefore, there is percent error which is a constant value for any given vertical load. This percent error is defined as the measured torque minus the true friction force times the tire radius divided by the friction force times the tire radius. Inflation pressure did have a marked effect on the error in some cases changing the displacement error by a factor of 2:1, with the error decreasing with increased pressure.

To simplify the data, ranges are shown in Fig. 14 for static hot and cold percent errors. Errors ranged from a low of 2% to a high of 11%. These data included radial, belted bias, and bias construction tires, as well as the ASTM E-17 standard pavement test tire. They represent different makes and sizes, and no particular type or make showed any semblance of a pattern except radials, which tended to provide slightly larger errors, however, only two samples were tested. Due to the difficulty of measuring errors of this type, the data are no better than a 1-1/2 percentage numbers. However, the data do indicate that important differences do exist from the standpoint of measuring techniques.

A second method of test involved dynamic measurement using the trailer equipped with a strain-gaged hitch ball and was used to verify the static data. Records were made of fore and aft hitch force, wheel torque, and vehicle acceleration. Vehicle acceleration was used to compensate

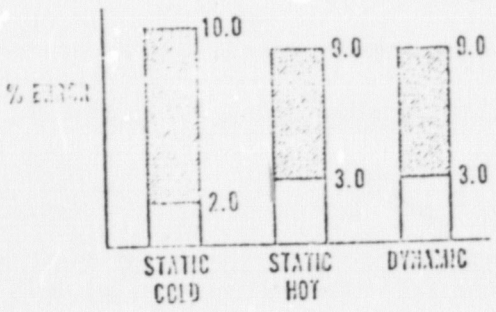


Fig. 15 - ...nstant error percentages for hot and cold static and ...ic tire tests

for inertia forces in the fore and aft force measurements. Fig. 15 shows the errors calculated for these data along with the static errors shown in Fig. 14. Differences did exist between individual static and dynamic data, however, the range between tires was nearly the same.

The conclusions which can be drawn from the data are complicated by the fact that the torque measuring trailers in existence are used for two distinct purposes. First, in terms of comparative tire testing, the data indicate that a torque measuring device can show nonexistent differences between tires. The highest measured error from the dynamic data was a radial ply tire with an error of 9% while the lowest error, a bias ply tire, was 3.0%. In this case, with an equivalent friction force capability, the radial ply tire will show a 6.0% improvement based on a torque measurement, or, in reverse, the brake must supply 6.0% more torque to provide the same friction force. The variation for an individual tire for hot and cold static and dynamic errors also indicate that patch point relocation cannot be accurately compensated for by calibrating each and every tire at each and every load and pressure. It must be concluded that a device to measure tire braking characteristics must measure friction force and not torque if differences between tires of less than 6% are to be defined with any degree of confidence. This error is exclusive of all other variables which effect traction testing.

The majority of skid trailers are operated by state highway departments and are used to survey roads. In this case, tests are performed using standard ASTM E-17 tires operating at the same load and pressure. Because of this, there may be an error in terms of absolute magnitude of about 6% based on dynamic patch point relocation error for an E-17 tire. However, data should compare on a test-to-test basis within a reasonable error band.

There are test groups, however, which calibrate torque transducers with simple torque arm or pure torque calibration, and some which use a drawbar or force technique with which patch point error would be compensated for by the same room temperature condition at the time of calibration. While the latter method would appear to be most suitable since it compensates to a some degree for patch point relocation, the authors would hesitate to recommend it because of the difficulty involved in building an accurate, frictionless, force calibrator. It is simpler to produce accurate torque calibrations using knife edge torque arms and weights and the equipment required is readily available and inexpensive. In any case, calibration methods must be standardized; a subject over which considerable thought should be given by individual users of skid trailers and groups writing ... for standards.

SUMMARY

General Motors Proving Ground has developed a very useful tool for use in evaluating road parameters both sliding and under slip conditions with a standard test tire. By means of this system, the authors have concluded that relocation of tire patch point under braking produces a sufficient error to negate the torque measuring technique as a means of comparing tires. The Model II system,* as designed, is readily adaptable to accommodate a force measuring system and work is presently under way to add the necessary transducers. When this modification is completed, the Proving Ground will have provided General Motors with an accurate tool for rapid evaluation of all facets of tire-road braking coefficient properties.

ACKNOWLEDGMENTS

The authors wish to acknowledge appreciation to all General Motors Proving Ground personnel for their assistance in the development of this material.

REFERENCES

1. Report of Committee E-17 on Skid Resistance, "Proposed Tentative Method of Test for Skid Resistance of Pavements Using a Two-Wheeled Trailer - E274-65T," Sixty-eighth Annual Meeting of ASTM, June 13-18, 1965.

2. V. E. Gough and S. G. Whitehall, "Universal Tire Test Machine." Dunlop Rubber Co., Ltd.

*Duplicate or modified versions of this system are available to interested parties. General Motors has arranged a free licensing agreement with an independent engineering firm.

PLAINTIFF'S EXHIBIT 140

No. 899. Motor Vehicles—Summary Statistics: 1950 to 1972

[Excludes Alaska and Hawaii, except as noted]

ITEM	1950	1955	1960	1965	1969	1970	1971	1972
SALES, EXPORTS, IMPORTS, AND SCRAPPAGE [1]								
Passenger car factory sales	6,666	7,920	6,675	9,306	8,224	6,546	8,853	8,824
4-door sedans	3,747	3,944	2,697	2,744	1,831	1,456	1,763	1,891
2-door sedans, coaches and coupes [2]	2,704	1,691	1,014	793	653	709	1,141	1,150
2-door and 4-door "hard-tops"	267	2,103	1,517	4,251	4,182	3,546	4,602	4,533
Convertibles (except "hard-top")	208	240	305	509	202	92	85	82
Station wagons [3]	142	737	1,053	1,001	821	662	984	1,152
Chassis	9	16	9	7	4	2	4	4
Truck and bus factory sales	1,337	1,240	1,194	1,752	1,923	1,692	2,053	2,447
Passenger cars (new), exported [4]	153	254	145	205	417	359	403	471
Passenger cars (new), imported	21	67	444	559	1,847	2,013	2,567	2,456
Exports	704	1,367	1,411	2,196	4,093	3,771	4,850	5,296
Passenger cars (new)	179	360	235	343	1,011	845	1,170	1,343
Trucks and buses (new)	217	340	362	328	365	436	649	714
Rubber tires and tubes	47	62	77	85	53	49	61	82
Parts and access. (excl. used veh.)	350	665	737	1,421	2,437	2,303	2,750	3,227
Imports of new passenger cars	21	69	513	640	3,355	3,719	5,134	5,704
Vehicles scrapped [5]	3,234	4,372	4,783	7,070	6,841	7,771	(NA)	(NA)
Passenger cars [6]	2,598	3,773	4,200	6,163	5,854	6,704	(NA)	(NA)
Trucks and buses [6]	636	599	583	907	987	1,067	(NA)	(NA)
PARTS AND CHEMICAL SHIPMENTS								
Tires, passenger car, [7] total	84.4	93.7	105.7	165.5	177.1	168.6	185.	155.0
Original equipment	36.7	42.6	36.3	51.4	41.2	37.5	44.	51.3
Replacement	47.1	50.2	68.5	94.9	124.1	124.6	135.	141.7
Export	0.6	1.0	0.9	2.2	1.9	1.5	1.	1.9
Tires, truck and bus, [7] total	15.2	14.6	13.9	20.4	27.4	25.7	29.1	33.0
Original equipment	4.7	4.6	3.9	6.9	9.5	6.6	10.3	12.6
Replacement	9.7	9.1	9.2	12.5	17.3	18.7	18.4	20.1
Export	0.8	0.9	0.8	0.7	0.6	0.4	0.4	0.4
Replacement automotive batteries [8]	24.4	25.8	26.3	29.5	34.5	37.9	39.1	[9]43.1
Sealed-beam lamps [10]	35.6	44.9	67.4	[9]85.6	[9]83.0	[9]76.2	[9]82.2	[9]92.4
Other automotive lamps [10]	251.2	331.4	323.4	[9]522.6	[9]617.4	[9]525.9	[9]576.1	[9]681.0
Antifreeze [11]	(NA)	110.0	120.9	143.1	164.2	156.1	192.6	(NA)
Heavy duty brake fluid [11]	(NA)	5.7	9.4	8.0	9.9	10.6	10.7	(NA)
SPECIAL MOTOR VEHICLE TAXES [4 12]								
Federal excise [13]	1.8	2.7	4.4	5.7	6.7	6.8	7.1	5.1
State motor veh. carrier receipts [12]	.9	1.5	1.9	2.5	3.5	3.8	4.1	[9]4.3
State motor fuel, net [12]	1.7	2.8	3.4	4.5	6.0	6.5	6.9	[9]7.8
MOTOR VEHICLE REGISTRATION [14]								
World	70.4	95.9	120.9	178.0	231.5	245.9	(NA)	(NA)
United States [15]	49.2	62.7	73.9	90.4	103.4	108.4	113.0	[9]117.6
Other North and Central America	3.2	4.9	6.8	8.7	10.5	11.3	(NA)	(NA)
South America	1.3	1.8	3.0	4.1	5.1	5.1	(NA)	(NA)
Europe	12.5	19.6	33.8	56.5	77.3	86.4	(NA)	(NA)
Africa	1.2	1.8	2.5	3.4	4.3	4.3	(NA)	(NA)
Asia	1.7	2.2	3.6	9.7	20.6	24.6	(NA)	(NA)
Oceania	1.4	2.6	3.5	4.7	5.4	5.0	(NA)	(NA)

NA Not available.

[1] Source: Exports and imports from U.S. Dept. of Commerce. [2] Includes fastback coupes. [3] Excludes station wagons on commercial vehicle chassis. [4] Includes export factory sales. [5] Estimated. [6] Includes Alaska and Hawaii. [7] Source: The Rubber Manufacturers Association, Inc., New York, N.Y. Beginning 1965, figures for "Tires, passenger car" include motorcycle tires. [8] Source: Battery Council International, Burlingame, Calif. [9] Preliminary. [10] Source: U.S. Bureau of the Census.

[11] Source: Chemical Specialties Manufacturers Association, Inc., New York, N.Y.

[12] Figures represent fluid compounded rather than sold.

[13] Special taxes on motor vehicle users. Excludes income and property taxes on motor vehicle, body, parts and tire factories, garages, dealers, repair shops, terminal and truck, including taxicab and bus, operating companies.

[14] Source: U.S. Dept. of the Treasury and U.S. Dept. of Transportation. Includes amounts collected on use of vehicles over 26,000 pounds as follows: in millions of dollars: Fed. 45, 1965, 103, 1967, 124, 1969, 141, 1971, 152, and 1972, 163. [15] Source: U.S. Dept. of Transportation.

[16] Includes cars, trucks, and buses. Source: Through 1969, U.S. Dept. of State and overseas sources; thereafter, U.S. Bureau of Domestic Commerce. *World Motor Vehicles Production & Registration, 1970 IV.*

Source: Motor Vehicle Manufacturers Association of the United States, Inc., Detroit, Mich., *Automobile Facts and Figures*. Includes data compiled from sources cited in footnotes.

[PX 140, p 1]

No. 900. Motor Vehicles—Factory Sales and Registrations: 1910 to 1972

[Prior to 1960, registrations exclude Alaska and Hawaii, except as noted. See also *Historical Statistics, Colonial Times to 1957*, series Q 310-317]

Year	Factory sales[1]: Number (1,000)			Factory sales[1]: Wholesale value[2]				Registrations[3] (1,000)			
				Passenger cars		Trucks and buses[3]					
	Total cars, trucks, buses	Passenger cars	Trucks and buses[3]	Total (mil. dol.)	Average[4]	Total (mil. dol.)	Average[4]	Total cars, trucks, buses	Passenger cars and taxis[5]	Trucks and buses[6]	Motorcycles
1910	187	181	6	215	$1,186	10	$1,667	1,400	458	15	—
1920	2,227	1,906	322	1,899	949	423	1,314	[9] 9,251	8,131	1,108	239
1930	3,368	2,787	575	1,644	590	391	680	[9] 29,794	23,035	3,743	108
1940	4,472	3,717	755	2,371	638	568	752	[9] 32,523	27,456	4,997	156
1945	4,135	3,717	418	2,831	762	368	880	49,300	41,339	8,421	454
1950	8,003	6,666	1,337	8,408	1,270	1,708	1,277	49,300	41,339	8,421	570
1960	7,869	6,675	1,194	12,164	1,822	2,321	1,959	73,869	61,642	12,197	575
1965	11,057	9,309	1,752	18,340	1,975	3,734	2,131	90,341	75,241	15,109	1,362
1967	8,926	7,435	1,539	15,653	2,105	3,592	2,334	96,887	80,305	15,499	1,583
1968	10,718	8,822	1,896	18,352	2,194	4,670	2,463	100,976	83,596	16,263	2,069
1969	10,147	8,224	1,923	18,254	2,260	4,837	2,567	106,654	88,855	16,221	2,316
1970	8,284	6,547	1,737	14,630	2,253	4,450	2,624	108,335	89,290	16,145	2,424
1971	10,638	8,585	2,053	21,419	2,494	5,954	2,905	112,993	92,749	20,200	3,343
1972	11,271	8,874	2,447	22,846	2,575	7,400	3,024	[11] 116,696	[10] 95,300	[11] 21,209	[11] 3,787

— Represents zero. [1] Beginning 1965, excludes tactical vehicles. [2] A substantial part of the trucks and buses reported comprises chassis without body; hence, excludes the value of bodies for these chassis. [3] Beginning 1960, includes value of standard equipment. [4] Averages do not indicate precise trends in unit prices since total values may reflect changes in number of makes, models, and or body types from year to year. [5] Includes possibly several vehicles. Excludes vehicles owned by military services. [6] Prior to 1930, buses included with passenger cars. [7] Total includes, components exclude, Hawaii. [8] Estimate.

Source: Factory sales: Motor Vehicle Manufacturers Association of the United States, Inc., Detroit, Mich., *Automobile Facts and Figures*, annual; registrations—U.S. Federal Highway Administration, *Highway Statistics*, annual.

No. 901. Motor Vehicles—Establishments, Sales, Payroll, and Employment for Selected Kinds of Business: 1963 and 1967

Kind of business	Establishments[1] (1,000)		Sales or receipts[2] (mil. dol.)		Annual payroll[3] (mil. dol.)		Paid employees[4] (1,000)	
	1963	1967	1963	1967	1963	1967	1963	1967
RETAIL TRADE								
Automotive dealers	**98.5**	**105.5**	**45,376**	**55,631**	**4,111**	**5,257**	**794.2**	**996.6**
Motor vehicle dealers—new and used cars	33.3	62.0	[35,375	48,636	3,336	4,732	612.1	906.3
Motor vehicle dealers—used cars only	28.0		3,067]		184	143	44.3	39.6
Tire, battery, and accessory dealers	25.9	29.2	3,335	4,236	474	664	119.3	129.6
Misc. automotive dealers	11.3	14.3	1,579	2,760	177	236	27.2	42.2
Gasoline service stations	**211.5**	**216.1**	**17,760**	**22,709**	**1,510**	**1,898**	**519.8**	**515.2**
WHOLESALE TRADE								
Motor vehicles and auto equipment	**29.4**	**31.2**	**36,789**	**45,122**	**1,871**	**2,127**	**293.7**	**341.1**
Automobiles and other motor vehicles	4.6	4.6	25,958	31,330	807	641	79.9	91.9
Automotive equipment	22.7	23.3	8,614	11,614	1,019	1,286	191.2	214.1
Tires and tubes	2.2	3.1	2,157	3,178	146	225	24.6	35.1
SERVICES								
Auto repairs, services, and garages	**139.6**	**139.2**	**5,444**	**[7]7,028**	**1,135**	**1,468**	**259.0**	**316.2**
Automobile repair shops	114.5	109.9	3,568	4,066	778	943	144.4	182.9
Automobile parking	11.3	10.6	416	484	114	129	34.9	33.5
Car, truck rental and leasing, other serv.	13.9	18.7	1,440	2,453	242	396	68.7	95.0
MANUFACTURING								
Motor vehicles and equipment	**2.8**	**2.7**	**12,781**	**13,666**	**8,194**	**8,930**	**493.8**	**[7]39.4**
Motor vehicles	2.0	0.2	[12,346	[7,334	4,947	[2,745	449.9	[7]371.2
Motor vehicle parts and accessories		1.7		5,712]		2,501]		341.9
Truck and bus bodies	0.6	0.6	230	332	133	192	21.5	30.4
Truck trailers	0.2	0.2	206	263	113	147	19.4	22.9

[1] As of Dec. 31; represents all establishments, except for wholesale trade and manufacturing, which represent only establishments employing one or more workers at any time during the year.
[2] For manufacturing, data represent value added in manufacture. [3] Comprises salaries, wages, commissions, bonuses, vacation pay, and other remuneration. [4] Workweek ended nearest Nov. 15, 1963, and week including Mar. 12, 1967, except quarterly average for manufacturing.
[5] Data corrected only at level significantly affected; therefore, breakdown will not add to total.

Source: U.S. Bureau of the Census, *Census of Business: 1967*, vols. II, VI, and VIII, and *Census of Manufactures: 1967*, vol. I.

No. 902. Motor-Vehicle Registrations, 1950 to 1972, and Drivers Licenses, 1971, by States

[In thousands, except as indicated. Motor-vehicle registrations include publicly, privately, and commercially owned vehicles; for uniformity, figures have been adjusted to a calendar-year basis as registration years in States differ; figures represent net numbers where possible, excluding re-registrations and nonresident registrations]

State	Automobiles, trucks, and buses							Motorcycles (incl. officials), 1972	Drivers licenses, 1971		
					1972					Percent	
	1950	1960	1965	1970	Total	Private and commercial			Total [1]	Male drivers	Drivers under 25 years
						Automobiles (incl. taxicabs)	Trucks and buses				
U.S. [2]	49,300	73,869	90,341	108,375	118,618	96,949	20,455	3,315	114,397	56.2	22.0
Ala	696	1,282	1,663	1,966	2,227	1,747	456	52	1,861	56.8	21.4
Alaska	(NA)	81	109	137	149	101	43	10	147	53.7	25.5
Ariz	271	624	825	1,093	1,302	972	315	43	1,173	55.6	24.8
Ark	477	708	914	1,043	1,070	733	326	24	1,084	56.8	21.9
Calif	4,620	7,599	9,969	11,901	12,852	10,560	2,170	615	12,133	55.0	20.9
Colo	564	924	1,156	1,442	1,680	1,271	388	57	1,475	53.4	27.0
Conn	716	1,107	1,415	1,733	1,860	1,648	153	43	1,569	53.2	21.1
Del	108	192	244	312	353	270	81	6	340	54.1	21.4
D.C	193	206	236	257	260	224	36	4	315	62.3	16.1
Fla	985	2,367	3,047	4,120	4,896	4,132	656	122	4,084	54.3	18.6
Ga	808	1,512	1,960	2,584	2,951	2,372	557	66	2,731	56.5	21.4
Hawaii	185	291	370	465	487	382	81	10	574	54.7	23.2
Idaho	272	375	434	474	550	382	156	22	541	57.7	26.0
Ill	2,651	3,776	4,437	5,238	5,644	4,901	703	135	5,903	56.3	22.5
Ind	1,435	2,046	2,427	2,818	2,969	2,506	584	85	2,804	54.1	23.9
Iowa	1,072	1,323	1,549	1,740	1,917	1,480	440	79	1,664	53.9	26.1
Kans	853	1,163	1,369	1,548	1,692	1,239	452	75	1,146	53.2	24.1
Ky	744	1,196	1,500	1,763	1,966	1,516	432	30	1,636	56.8	21.6
La	707	1,177	1,442	1,742	1,942	1,518	410	34	1,813	56.8	21.7
Maine	276	373	424	510	565	451	109	13	549	55.6	21.1
Md	665	1,155	1,451	1,872	2,130	1,832	295	35	2,073	55.1	21.9
Mass	1,250	1,862	2,104	2,553	2,822	2,543	279	58	3,093	54.0	21.7
Mich	2,433	3,396	3,991	4,569	5,011	4,268	743	194	5,213	54.7	21.3
Minn	1,169	1,592	1,800	2,207	2,395	1,872	523	89	2,315	57.1	23.4
Miss	464	725	921	1,117	1,249	929	319	20	1,327	58.5	22.3
Mo	1,261	1,730	2,085	2,468	2,618	2,057	562	68	2,719	55.7	23.2
Mont	265	373	429	485	584	375	201	30	421	55.6	22.3
Nebr	569	734	840	974	1,081	776	304	38	1,033	53.7	25.3
Nev	77	175	266	355	399	295	93	19	351	55.4	20.7
N.H	172	267	314	392	436	368	63	13	441	55.3	21.1
N.J	1,579	2,431	2,960	3,546	3,859	3,463	346	57	4,054	55.7	20.0
N. Mex	238	426	525	637	711	540	301	27	649	55.8	25.1
N.Y	3,735	5,667	5,903	6,718	7,119	6,351	684	75	8,275	57.4	18.9
N.C	1,050	1,720	2,156	2,826	3,230	2,630	636	69	2,835	55.1	25.4
N. Dak	256	345	396	474	494	380	167	13	341	55.7	25.6
Ohio	2,755	4,057	4,935	5,974	6,224	5,457	674	152	5,998	60.5	19.7
Okla	831	1,184	1,435	1,713	1,882	1,326	537	71	1,657	53.8	23.7
Oreg	689	919	1,119	1,369	1,496	1,237	260	70	1,369	54.1	19.3
Pa	3,010	4,267	4,968	5,818	6,311	5,690	622	117	6,312	58.6	21.6
R.I	251	341	406	488	536	475	58	13	527	55.0	21.1
S.C	579	879	1,094	1,360	1,447	1,210	238	14	1,466	57.5	19.3
S. Dak	240	354	398	426	463	312	151	11	415	55.1	26.3
Tenn	858	1,305	1,655	2,050	2,294	1,810	484	58	2,088	55.2	23.2
Tex	2,906	4,455	5,610	6,993	7,316	5,553	1,763	186	6,548	55.9	23.5
Utah	247	417	525	664	741	538	192	36	527	60.0	25.8
Vt	121	152	178	224	261	218	43	9	268	55.2	21.0
Va	918	1,426	1,800	2,263	2,603	2,167	436	41	2,463	57.0	22.6
Wash	924	1,377	1,659	2,102	2,242	1,702	540	75	1,900	54.7	23.1
W. Va	482	693	806	891	874	669	205	47	982	54.2	24.3
Wis	1,201	1,660	1,839	2,141	2,357	1,971	385	60	2,465	56.0	23.9
Wyo	142	207	225	247	274	174	98	12	231	57.8	25.5

NA Not available.
[1] Excludes vehicles owned by military services.
[2] Estimated from data reported by States for current and previous years; allowance has been made for deaths, emigration, or revocation by some States.
[3] Incomplete data for some States.

Source: U.S. Federal Highway Administration, *Highway Statistics*, annual; *Drivers Licenses*, annual; and unpublished data.

No. 903. New Passenger Car Production and Imports: 1963 to 1972

ITEM	1963	1965	1966	1967	1968	1969	1970	1971	1972
Value of production:									
Gross auto product [1] ... bil. dol.	25.1	31.8	30.0	28.9	36.3	36.6	30.7	40.9	43.1
Gross national product [2] ... bil. dol.	590.8	654.9	749.9	793.9	864.2	930.3	976.4	1,050.4	1,151.8
Gross auto product as percent of GNP ...	4.3	4.6	4.0	3.6	4.2	3.9	3.1	3.9	3.7
Production and imports:									
Total ... 1,000 units	8,053	9,894	9,515	8,434	10,469	10,071	8,853	11,171	11,314
Domestic production ... 1,000 units	7,644	9,305	8,635	7,413	8,819	8,224	6,553	8,581	8,828
Imports ... 1,000 units	409	589	913	1,021	1,650	1,847	2,013	2,567	2,486
Percent of total ...	5.1	5.6	9.6	12.1	15.8	18.3	23.5	23.2	22.0

[1] Value of domestically produced cars plus net value added by distribution of new, used, and imported cars. [2] For definition, see text, p. 317.

Source: U.S. Bureau of the Census and U.S. Bureau of Economic Analysis, unpublished data.

No. 904. Automobiles—Factory Installed Equipment: 1960 to 1972

[Refers to model-year production. For certain items, such as air conditioning, a significant number of units are installed on new vehicles after they leave the factory]

EQUIPMENT	UNITS INSTALLED (1,000)					PERCENT OF CARS PRODUCED				
	1960	1965	1970	1971	1972	1960	1965	1970	1971	1972
Automatic transmission	4,306	7,134	7,213	6,673	8,222	71.6	83.7	91.0	93.2	91.9
Manual transmission	1,706	1,709	709	728	735	28.4	19.3	8.9	9.6	8.1
V-8 engine	3,409	6,492	6,674	5,963	7,146	56.7	73.4	84.2	75.8	79.9
6-cylinder engine	2,603	2,350	1,247	1,006	802	43.3	26.5	15.7	13.2	13.7
4-cylinder engine	1,949	2,856	4,437	4,455	6,023	32.4	32.3	56.0	59.3	67.4
Power brakes										
Power steering	2,352	5,270	6,433	6,026	7,541	39.2	59.6	81.2	79.7	84.3
Power windows [1]	376	1,261	1,319	1,097	2,035	6.3	14.3	16.7	14.5	23.0
Air conditioning	414	2,061	4,835	4,612	6,135	6.9	23.3	61.0	61.0	68.6
Tinted glass [2]	1,668	4,572	5,507	5,246	6,653	27.7	51.7	69.5	69.4	74.8

[1] Includes power operated station wagon rear windows. [2] Covers windshield and other glass.

Source: Chilton Company, Radnor, Pa. *Annual Statistical Issue, Automotive Industries.* (Copyright.)

No. 905. Automobile Ownership, Age, and Financing: 1950 to 1971

[Excludes Alaska and Hawaii. For definition of family unit, see headnote, table 561]

ITEM	1950	1955	1960	1965	1966	1969	1970	1971
Total number of families in U.S. [1] ... millions	45.2	49.1	53.4	58.4	61.2	62.1	63.7	65.1
Families owning automobiles ... percent	59	70	77	79	79	79	82	83
Owning 1 automobile ... percent	52	60	62	53	53	52	54	55
Owning 2 or more automobiles ... percent	7	10	15	24	26	27	28	28
Automobiles owned, by age: [2]								
Less than 2 years old ... percent	17	12	14	16	14	15	16	11
2 and 3 years old ... percent	19	22	20	21	24	22	21	25
4-7 years old ... percent	6	43	41	33	36	41	42	40
8 years old and over ... percent	58	23	25	30	26	22	21	24
Total automobiles purchased [3] ... millions		13.6	14.1	19.2	19.2	20.5	19.6	19.3
New cars ... millions		4.4	5.2	7.7	6.9	7.5	8.3	8.9
Average price paid ... dollars	(NA)	(2,730)	3,140	3,140	3,240	3,580	3,690	(3,690)
Used cars ... millions		9.2	9.1	11.3	12.3	13.0	11.3	12.4
Average price paid, gross ... dollars		780	980	920	1,090	1,000	1,110	(1,270)
Method of financing purchases:								
All passenger cars [4] ... percent	100	100	100	100	100	100	100	100
Full cash (including trade-in allowance) ... percent	47	38	38	48	42	47	47	50
Installment credit and other borrowing ... percent	52	60	62	52	58	53	53	50
New passenger car buyers [5] ... percent	100	100	100	100	100	100	100	100
Full cash (including trade-in allowance) ... percent	54	39	33	40	31	34	34	43
Installment credit and other borrowing ... percent	46	60	67	60	69	66	66	57
Used passenger cars [5] ... percent	100	100	100	100	100	100	100	100
Full cash (including trade-in allowance) ... percent	41	37	41	53	50	51	52	50
Installment credit and other borrowing ... percent	57	60	59	47	50	49	48	50

NA Not available. [1] At time of survey, early in year indicated. [2] Covers family units buying cars during preceding calendar year and still owning them at time of survey (January–February of year indicated). [3] Age is determined by subtracting model year from year of survey. [4] Data may be unreliable due to an unusually small sample. [5] Refers to purchases during preceding year. Includes cars received as gifts, whether cash or credit purchased. Buyers for whom method of financing was not ascertained are excluded from the detail on purchases.

Source: The University of Michigan, Survey Research Center, Ann Arbor, Mich., *Surveys of Consumer Finances.*

No. 906. Household Expenditures on New and Used Cars: 1968 to 1973

[Seasonally adjusted. Annual figures are averages of quarterly rates, except purchases per 100 households. Expenditures and prices are net of trade-in allowances and state and Federal taxes. Based on sample]

YEAR AND QUARTER	PURCHASES PER 100 HOUSEHOLDS		EXPENDITURES, ANNUAL RATE (bil. dol.)			AVERAGE PRICE (dollars)	
	New cars	Used cars	Total	New cars	Used cars	New car	Used car
1968	13.2	22.2	35.1	23.2	11.9	2,912	858
1969	13.0	20.8	35.4	24.4	12.0	3,031	941
1970	11.1	19.6	33.3	21.3	12.0	3,014	959
1971	12.4	22.4	41.7	26.9	14.8	3,305	1,021
1972	12.8	22.5	44.8	28.8	16.0	3,350	1,066
1973, Jan.-Mar	13.9	24.9	52.6	32.4	20.2	3,476	1,190

Source: U.S. Bureau of the Census, *Current Population Reports*, series P-65, Nos. 33, 45, and 48.

No. 907. Estimated Cost of Operating an Automobile: 1960, 1970, and 1971

[1971 estimates based on a 4-door sedan, costing $4,379, with an assumed life-span of 10 years, 100,000 miles. Similar specifications used in 1960 and 1970]

ITEM	10 YEAR TOTAL COSTS			CENTS PER MILE COST, 1971 (January)					
	1960 (Oct.)	1970 (Jan.)	1971 (Jan.)	10-year average	1st year (11,500 miles)	3d year (11,500 miles)	5th year (9,700 miles)	7th year (9,500 miles)	10th year (5,700 miles)
Total	$9,761	$11,890	$13,553	13.55	16.04	14.39	13.62	13.18	10.43
Costs excluding taxes	8,595	10,537	12,234	12.23	13.79	13.30	12.47	12.01	9.64
Depreciation	2,542	3,165	4,379	4.38	8.46	5.87	3.80	1.99	.84
Repairs and maintenance [1]	1,722	1,821	2,147	2.15	.56	2.11	2.58	4.19	.51
Replacement tires and tubes [2]	181	365	460	.40	.12	.21	.44	.63	.74
Accessories [3]	140	28	52	1.00	.02	.03	.03	.09	.10
Gasoline [4]	1,453	1,733	1,978	1.98	1.98	1.98	1.98	1.98	1.98
Oil [4]	187	158	119	.12	.04	.10	.13	.14	.12
Insurance [5]	1,290	1,722	1,350	1.35	1.13	1.36	1.43	1.22	2.04
Garaging, parking, tolls, etc. [6]	1,080	1,805	1,809	1.81	1.44	1.65	1.80	1.67	2.71
Taxes and fees [7]	1,166	1,353	1,319	1.32	2.25	1.09	1.15	1.17	1.39

[1] For 1971, includes lubrications, repacking wheel bearings, flushing cooling system, and adding headlamps' replacement of minor parts such as spark plugs, fan belts, radiator hoses, distributor cap, fuel filter, and pollution control filters; minor repairs such as brake jobs, water pump, carburetor overhaul and universal joints, and major repairs such as a complete "valve job."

[2] For 1971, covers 3 new regular tires and 4 new snow tires during life of car.

[3] For 1971, includes a set of vinyl floor mats and seat covers. [4] For 1971, gasoline use set at 13.6 miles per gallon; associated oil use at 1 gallon oil to 186 gallons gas.

[5] For 1971, includes $100,000 combined public liability ($15,000/$30,000 bodily injury, and $5,000 property damage), $1,000 medical payments, uninsured motorist coverage, and full comprehensive coverage for the 10-year period; $100 deductible collision insurance was assumed for the first 5 years.

[6] For 1971, includes monthly charges of $10 for garage rental or cost of owner's garaging facility, parking fee average of $54 per year, and toll average of $6.91 per year. [7] For 1971, includes Federal excise taxes on tires of 10 cents per pound, lubricating oil of 6 cents per gallon, and gasoline of 4 cents per gallon, plus the Maryland tax on gasoline of 7 cents per gallon, titling tax of 4 percent of retail price, and registration fee of $20.00 for 3,700 pounds or less shipping weight, or $30.00 for vehicles over 3,700 pounds.

Source: U.S. Federal Highway Administration, *Cost of Operating an Automobile*.

No. 908. Cars and Trucks in Use, by Age: 1955 to 1972

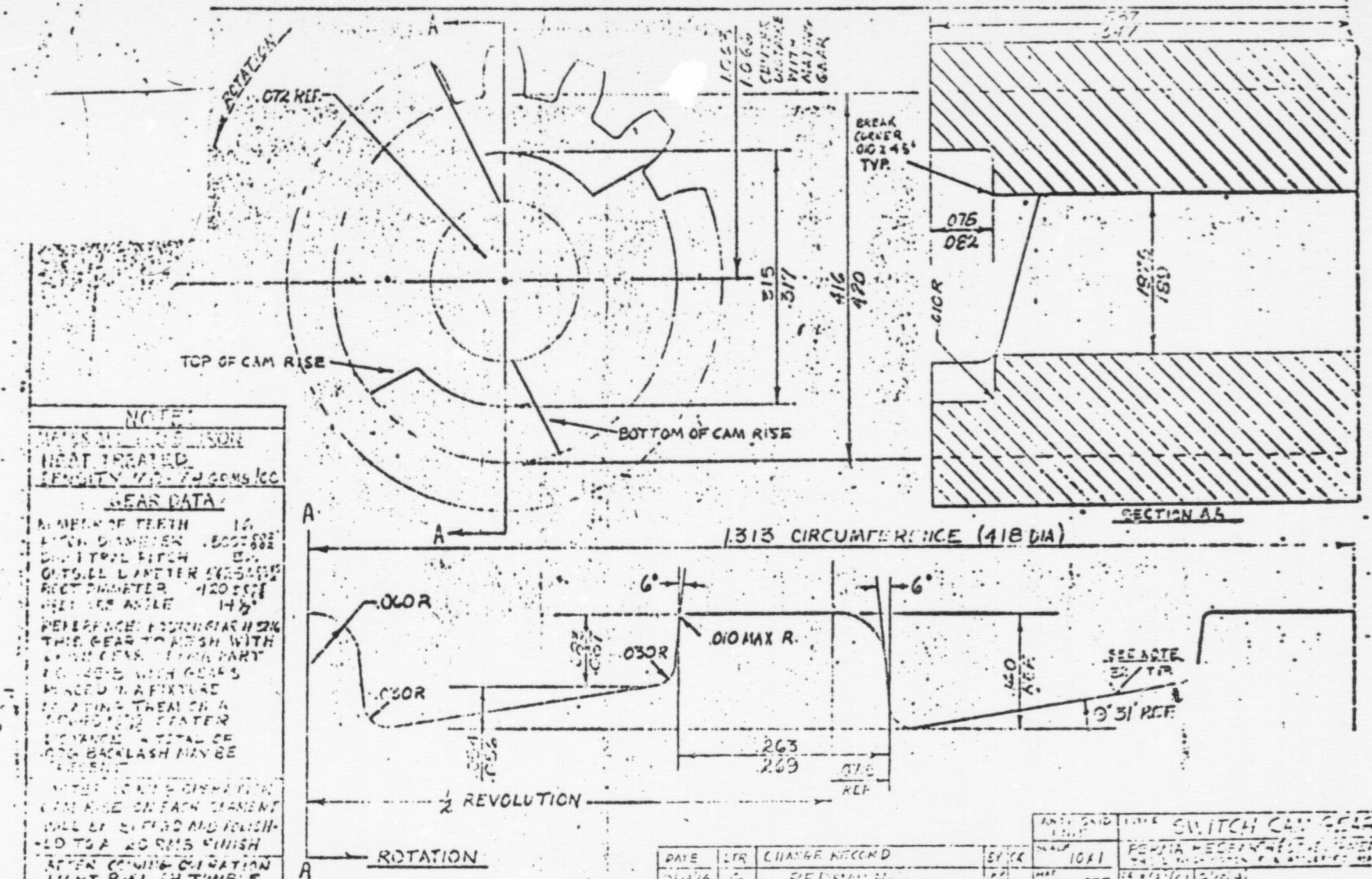
[As of July 1. Prior to 1960, excludes Alaska and Hawaii. Excludes vehicles for which age was not known]

AGE	1955		1960		1965		1970		1972	
	Number (1,000)	Percent	Number (1,000)	Percent	Number (1,000)	Percent	Number (1,000)	Percent	Number (1,000)	Percent
Total cars	47,123	100.0	56,935	100.0	68,935	100.0	80,427	100.0	86,412	100.0
Under 3 years	14,448	30.7	14,186	24.9	21,578	31.3	24,433	30.3	24,934	28.9
3-5 years	15,164	32.2	18,348	32.2	18,013	26.1	24,903	31.0	25,216	29.2
6-8 years	10,146	21.5	12,360	21.7	13,571	19.7	18,441	22.9	21,434	24.8
9-11 years	7,365	15.6	9,199	16.2	9,862	14.3	7,735	9.6	9,869	11.4
12 years and over			2,838	5.0	5,911	8.6	4,925	6.1	4,947	5.7
Total trucks	9,111	100.0	10,771	100.0	13,106	100.0	17,672	100.0	19,748	100.0
Under 3 years	2,039	22.4	2,046	19.0	3,222	24.6	4,660	26.5	5,164	26.1
3-5 years	2,767	30.4	2,418	22.4	2,476	18.9	4,253	24.1	4,625	23.4
6-8 years	2,319	25.5	2,077	19.3	1,950	14.9	2,975	16.7	3,735	18.9
9-11 years	702	7.7	2,332	21.7	1,844	14.1	1,862	10.5	2,121	10.8
12 years and over	1,285	14.1	1,898	17.6	3,614	27.6	3,925	22.2	4,073	20.6

Source: R. L. Polk & Co., Detroit, Mich. Further reproduction prohibited without Polk permission.

[PX 142, p 1]

PLAINTIFF'S EXHIBIT 142



NOTE:
MATERIAL: CASE HARDENING STEEL
HEAT TREATED
HARDNESS [illegible]

GEAR DATA:
NUMBER OF TEETH 16
PITCH DIAMETER .500/.502
DIAMETRAL PITCH 32
OUTSIDE DIAMETER .532/.534
ROOT DIAMETER .420/.422
PRESSURE ANGLE 14½°
REFERENCE FOR GRIND II 2% THIS GEAR TO MESH WITH MATING GEAR PART [illegible] GEARS WITH GEARS MOUNTED IN A FIXTURE OPERATING THEREON IN A HOUSING OR THE EQUIVALENT TOTAL OF .006 BACKLASH MAY BE PRESENT

WHERE NOTED ON DRAWING SURFACE ON EACH SEGMENT SHALL BE SHOT PEENED AND POLISHED TO A 20 RMS FINISH

AFTER COMPLETE OXIDATION LIGHT BURNISH TUMBLE

DATE	LTR	CHANGE RECORD	BY	CK
10/3/64	G	REDRAWN		
11/16/64	H	ROOT DIA. WAS .420/.422 NOW .420/.422 PITCH DIA. WAS .500/.502 NOW .500/.502		

MATL SPEC: 1041
HEAT TREAT: SEE NOTE
FINISH: SEE NOTE
OTHER SPECS:

TITLE: SWITCH CAM GEAR
PENN ENGINEERING & MANUFACTURING CORP.
DWG. NO. 101-H

[PX 142, p 1]
E-713
("Note" at top of page transcribed on page E-713A)

After viewing all available copies of the preceding page, counsel for Appellant believes that the "Note" at the top of the page thereof reads as follows:

"NOTE:

MATERIAL (HQS?) IRON
HEAT TREATED
DENSITY 70-74 GRMS/CC

GEAR DATA

NUMBER OF TEETH	16
(?) DIAMETER	.500 + .002
(?) PITCH	52(?)
OUTSIDE DIAMETER	(?)
(?) DIAMETER	.120 + .005
(?)... AXLE	14 1/2"

(?)... THIS GEAR TO MESH WITH (?) GEAR PERMA PART NO LESS WITH GEARS PLACED IN A FIXTURE (?) THEM ON A (?) CENTER DISTANCE A TOTAL OF .006 BACKLASH MAY BE PRESENT

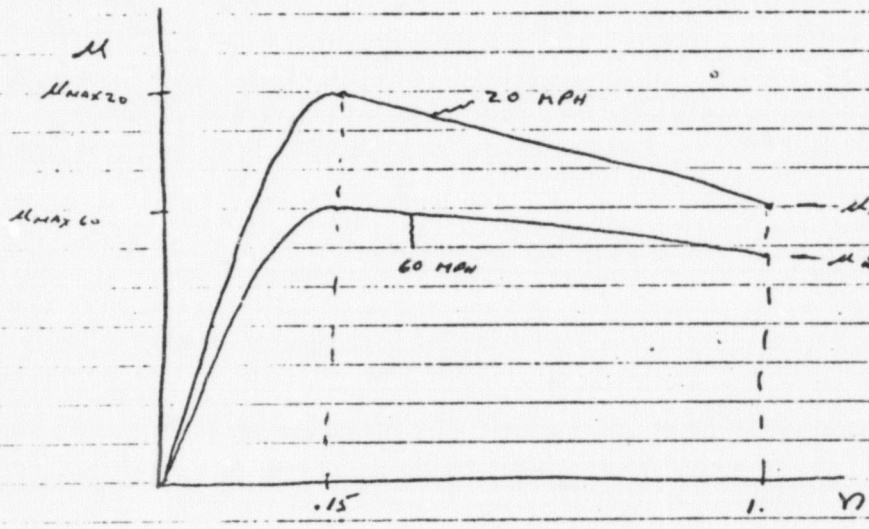
WITH COMING OPERATION CAM (?) RISE ON EACH SEGMENT WILL BE BUFFED AND POLISHED TO A (?) FINISH

AFTER COMING OPERATION LIGHT(BURNISH?) TUMBLE"

PLAINTIFF'S EXHIBIT 143

ROAD SURFACES DENOTED BY 60 MPH SLIDING COEFFICIENT OF FRICTION.

FRICTION MODEL



[PX 143, p 1]

ROAD TIRE FRICTION MODEL

$$\mu = \mu_{MAX}\left[2\left(\frac{n}{n_{PK}}\right) - \left(\frac{n}{n_{PK}}\right)^2\right] \qquad n \le n_{PK}$$

$$\mu = \mu_{MAX} - \frac{\mu_{MAX} - \mu_{SL}}{1 - n_{PK}}\left(n - n_{PK}\right) \qquad n > n_{PK}$$

μ_{MAX}, μ_{SL} ARE LINEAR FUNCTIONS OF VEHICLE VELOCITY BETWEEN 60 AND 20 ~~MPH~~. THE 60 AND 20 ~~MPH~~ VALUES ARE RESPECTIVELY APPLIED ABOVE 60 AND BELOW 20 MPH.

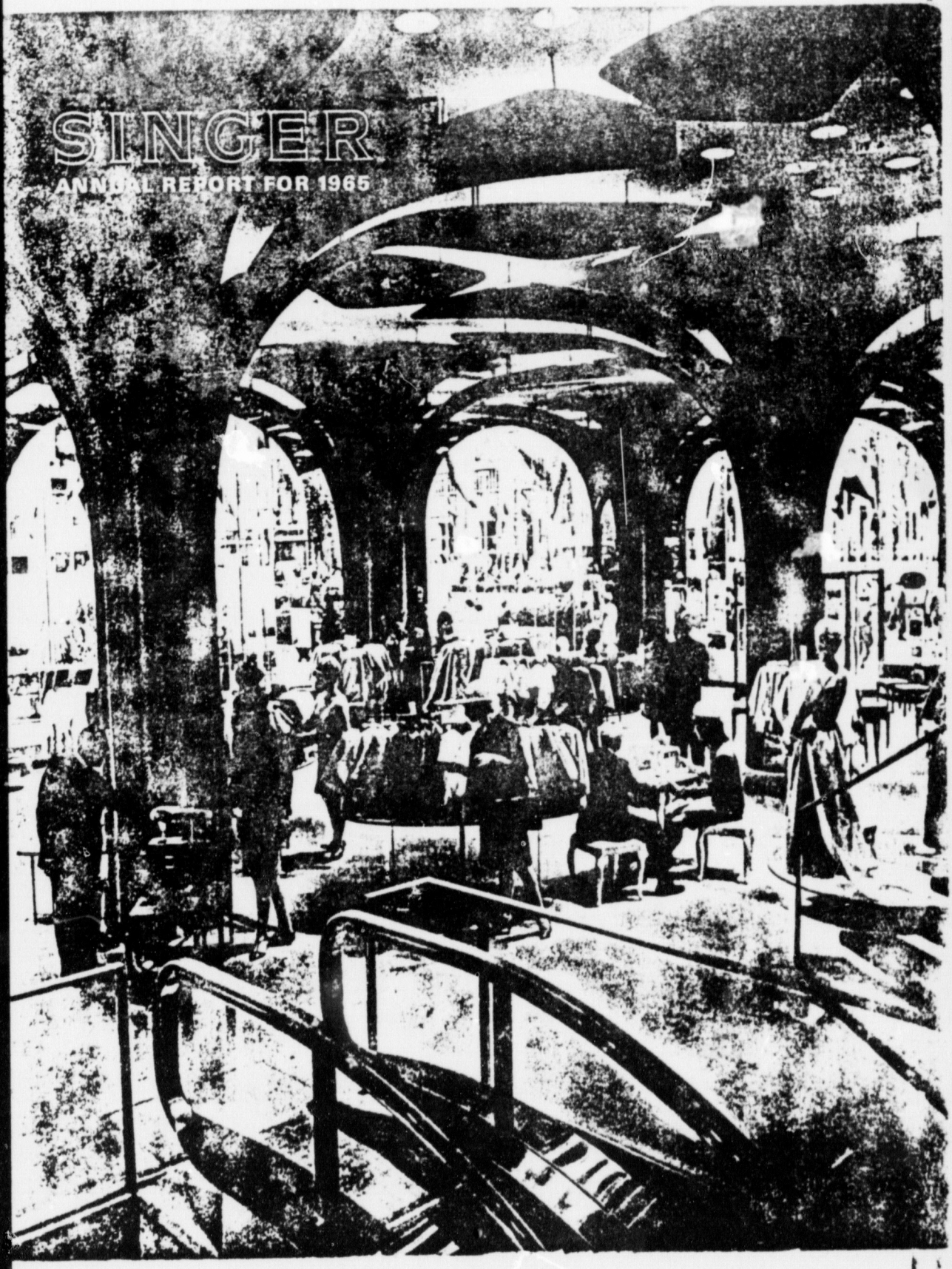
$n = 1 - \frac{rw}{V}$ WHERE r IS ROLLING RADIUS IN FEET, w IS WHEEL ANGULAR VELOCITY IN RADIANS PER SECOND, V IS VEHICLE VELOCITY IN FEET PER SECOND.

[PX 143, p 2]

BRAKE MODEL

T_R = BRAKE TORQUE PER

ROAD	μ_{MAX} 60	μ_{MAX} 20	μ_{SLIDE} 60	μ_{SLIDE} 20
.75	.788	.938	.75	.75
.7	.735	.875	.7	.7
.5	.725	1.01	.5	.75
.2	.31	.31	.2	.2
.15	.2325	.2325	.15	.15


SINGER
ANNUAL REPORT FOR 1965

UEEHOLD SEWING MACHINES • FABRICS • PATTERNS • NOTION
ACUUM CLEANERS • FLOOR WAXERS AND POLISHERS • PORTABL
PEWRITERS • KNITTING MACHINES • REFRIGERATORS • WASHI
INES • KITCHEN RANGES • ELECTRIC HEATERS • PORTABL
LECTRIC POWER TOOLS • RADIOS • PHONOGRAPHS • PHONO
APH RECORDS • HI-FIDELITY COMPONENTS • TAPE RECORDER
TELEVISION SETS • DATA PROCESSING EQUIPMENT • ADDIN
ACHINES • CALCULATORS • INDUSTRIAL SEWING MACHINES ANI
LIED EQUIPMENT • TUFTING MACHINES • HOSIERY KNITTIN
CHINES • CIRCULAR KNITTING MACHINES • DYE BECKS • PO
E MACHINES • MAILROOM EQUIPMENT • GRAPHIC ART
QUIPMENT • DOCUMENT CONVEYING SYSTEMS • COPY OF
CKETS • TICKET PRINTERS • SPECIAL PURPOSE ELECTRIC MOTO
POWER TOOLS • LATEX OVENS • ELECTRIC SPACE HEATER
AIR CONDITIONING EQUIPMENT • FREEZE PROTECTION DEVICE
DEHUMIDIFIERS • VENTILATING EQUIPMENT • TUBE REINFORCIN
ACHINES • GLOVE TURNING AND FORMING MACHINES • DOW
ING EQUIPMENT • SPECTRUM ANALYZERS • SIGNAL GENERATOR
MICROWAVE TEST INSTRUMENTS • PRIMARY STANDARDS FOR
OLTAGE CURRENT AND POWER • RADIO FREQUENCY INTERFERENCE
ST EQUIPMENT • TRANSFER STANDARDS • INFRARED SYSTEMS
BROADBAND AMPLIFIERS • DATA PROCESSING DEVICES • CLUTC
AKE MOTORS • BEACON TRANSMITTERS • SERVOMOTORS
RESOLVERS • INDUSTRIAL CONTROLS • SILICO-CERAMIC INSULATION
ATERIALS • COUNTERMEASURES • COMMUNICATIONS • TECHNICAL
TELLIGENCE • SYSTEMS ANALYSIS • OPERATIONS RESEARCH
RECONNAISSANCE • ENVIRONMENTAL TESTING • OPTICS

SINGER

30 Rockefeller Plaza, New York, N. Y. 10020

ANNUAL REPORT FOR 1965

Directors

CHARLES F. BRUDER
STEPHEN C. CLARK, JR.
GILBERT W. FITZHUGH
WALTER S. JOHNSON
H. NEAL KARR
DONALD P. KIRCHER
MILTON C. LIGHTNER
ARTHUR E. PETTIT
DONALD G. ROBBINS, JR.
PHILIP R. SAMWELL
ROBERT W. STEWART
JAMES A. TRAINOR

Officers

DONALD P. KIRCHER, President
RALPH P. BENN, Vice President
CHARLES F. BRUDER, Vice President
HERBERT BURCHILL, Vice President
HAROLD R. CRAWFORD, Vice President
ALFRED DI SCIPIO, Vice President
GEORGE A. DOWNSBROUGH, Vice President
ALAN W. DREW, Vice President
DAVID A. GRAESSER, Vice President
EDWIN J. GRAF, Vice President
NEWTON H. HOYT, JR., Vice President and Treasurer
H. NEAL KARR, Vice President
HENRY W. MANVILLE, Vice President
DONALD D. MARSDEN, Vice President
ROBERT E. PEQUIGNOT, Vice President
DONALD G. ROBBINS, JR., Vice President
ELLIOTT E. VOSE, Vice President
ANDREW J. REINHART, Controller
LOUIS L. PETTIT, Secretary

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ANNUAL MEETING

The Annual Meeting of Shareholders of the Company will be held at The Plaza Hotel, 768 Fifth Avenue, New York, New York, on Thursday, April 28 at 10:30 a.m.

TRANSFER AGENTS

Bankers Trust Company, New York, N. Y.
Crocker-Citizens National Bank, San Francisco, Calif.
Registrar and Transfer Company, Jersey City, N. J.

REGISTRARS

Morgan Guaranty Trust Company of New York, New York, N. Y.
The Bank of California National Association, San Francisco, California
Commercial Trust Company of New Jersey, Jersey City, N. J.

The Cover *The Singer Center opened at New York's Rockefeller Center last summer provides a glittering showcase for the household products sold by the Company in the United States.*

[PX 144, p 3]

Financial Highlights

	1964	
$896,239,000	$979,757,000	Net sales
904,359,000	988,232,000	Total revenue
46,494,000	44,496,000	Net income
4.19	4.03	Per share
22,174,000	24,313,000	Cash dividends
2.00	2.20	Per share
426,354,000	436,203,000	Shareholders' equity
38.42	39.50	Per share
356,725,000	354,251,000	Working capital
2.3	2.1	Current ratio
142,554,000	155,400,000	Property, plant and equipment —net
27,971	32,323	Number of shareholders at year end
11,097,074	11,043,517	Average shares outstanding

March 18, 1966

The volume of the Company's business continued to grow at a good rate in 1965. Consolidated sales increased for the seventh consecutive year, reaching $979.8 million, the highest point in history, and representing an increase of $83.6 million, or nine per cent over 1964.

Consolidated earnings for the year 1965 were $44.5 million, or $4.03 per share, a decrease of four per cent from the record earnings in 1964 of $46.5 million, or $4.19 per share.

In 1965 sales increased in all major geographical areas. The largest gain was in the United States where sales increased by 14 per cent, whereas sales abroad increased by five per cent. The lesser rate of sales growth abroad was largely a consequence of operations in Europe, where sales were only very slightly above the level of 1964, principally as a result of the slackening in the rate of economic growth in most European countries and the market disruptions caused by these new conditions. On a worldwide basis, sales of all major product lines, with the exception of industrial sewing products and instrumentation, increased significantly.

Perhaps the most important marketing achievement of the year occurred in our U. S. sales of household sewing machines. Unit sales increased by 14 per cent reaching the highest level in history. At the same time imports of competitive machines, which is our only reliable indicator of competitive sales, declined. Imports from Japan, which comprised 95 per cent of total imports, declined by one per cent and those from Europe by ten per cent.

In the aggregate, failure of net income to keep pace either with the previous six-year trend or with the increase in volume in 1965 was attributable to a large decline in earnings from European operations. The impact of declining growth rates in most European economies upon market conditions in most of our product lines was severe. Sales were generally sluggish and profit margins markedly lower. This situation was compounded by serious production and labor difficulties at Clydebank Factory in Scotland. These European problems were not all environmental. The decline in profitability revealed weaknesses in our own organization which had not been evident under previous boom conditions. Quite drastic changes were made in management, in organizational structure, and in operating methods. Many of these changes were made early in the year as soon as the trend became clear. In the latter months of the year the effect of these changes began to be felt and earnings improved somewhat. The improvement has continued in the current year.

The results in Europe were partially offset by improved earnings in the United States, in Latin America, where there was an excellent recovery in the second half of the year, and in Africa and the Near East.

No significant acquisitions were completed during 1965. In February of 1966 we contracted to purchase for approximately $16 million in cash a majority interest in Friedrich Schwab and Company, the third largest mail order company in Germany. Schwab currently has annual sales of about $110 million. In addition to an extensive mail order business in Germany, Schwab operates in that country a chain of about 40 small retail stores and four department stores. The transaction is scheduled to be completed in the second quarter and is subject to a comprehensive audit. A number of other possible acquisitions are currently under study and some are in the negotiating phase.

At mid year a new operating Division was created which brings together under single divisional control the U. S. marketing, production, and product development activities

primarily concerned with consumer products. The new Division, known as the Consumer Products Division, will thus have unitary responsibility for these product lines in the United States from the product development phase through manufacturing and the ultimate retail sale, service and financing to the consumer.

At the end of the year a similar step was taken in Europe which placed under single divisional control the marketing activities conducted by the European Division together with consumer products manufacturing operations in Continental Europe. This move virtually completed the program to integrate the manufacturing function throughout the Company with the primary marketing and other functions.

In the manufacturing field an expanded corporate staff group will provide coordination, technical direction, and assistance to the various operating divisions. In view of the seriousness of the problems at Clydebank Factory, a Vice President of the Company was appointed Managing Director of the factory early in 1965 and this executive reports directly to the President of the Company.

In August, the Company's total activities in the electric heating and air conditioning fields were consolidated to form a new Climate Control Division with headquarters in Auburn, New York. This Division incorporates the operations formerly conducted as the Electromode Division of Friden with those of Remington and Easy Heat/Wirekraft, two companies acquired in 1964. The Climate Control Division, while not yet large in the context of the total Company, is nevertheless the most rapidly growing operating division in the Company, and it has a bright future.

In connection with the U. S. Government's voluntary program relating to balance of payments, we were able to achieve during the year a good result in terms of the net inflow of dollars from those international transactions which were subject to the voluntary program. In fact, our performance exceeded somewhat the targets for the Company. The scope of the voluntary program has been expanded for 1966 and particular emphasis is being placed by the Administration upon restraint in the field of direct investment in developed countries. The impact of this program upon the Company in the current year is not yet precisely clear, but we do not expect that any substantial modification of our plans or programs will be required except to the extent of greater-than-normal foreign financing of projects abroad.

Early in the current year Max L. Waterman retired from the Board of Directors. Mr. Waterman had served as a member of the Board since 1949. He retired from active employment in 1960 at which time he was Vice President in charge of Research and Development. Mr. Waterman's advice and counsel as a Director have been valuable over the years. On March 10, Gilbert W. Fitzhugh, President of the Metropolitan Life Insurance Company, was elected a Director to fill the vacancy caused by Mr. Waterman's retirement.

During the year the Company continued to purchase its own shares to be available for use under the employee stock purchase and stock option plans and for future acquisitions. These purchases have continued in the current year. At March 11, 1966, there were 567,935 shares held in the treasury. At that date outstanding shares totaled 10,665,780.

The quarterly dividend was increased from 50 cents per share to 55 cents in the first quarter of 1965, and this rate remained in effect since that time. The dividend declared on February 10, 1966 was the 390th consecutive dividend paid by the Company. At the end of 1965, there were 32,323 shareholders, an increase during the year of 4,352.

In 1964 we determined that the increasing size and diversity of the Company required a more formalized system of long-range planning than had previously been in effect. In

1965, after much preliminary work, we initiated a formal long-range planning program, under which each of the operating divisions has established a five-year plan containing specific objectives. The program is intended to focus attention at all managerial levels upon the need for undertaking at a sufficiently early date the specific actions required to produce planned results in subsequent years. Since 1958, the year when programs for the growth and change of the enterprise were formulated and put into effect, our sales have doubled and our per-share earnings have more than tripled. The formalized long-range planning program is intended to aid in improving the future sales and earnings growth of the Company.

Although problems and difficulties facing the Company, internal and external, have not been entirely overcome (as they never are), the Management of the Company expects improvement in both sales and earnings in 1966. The improved results in last year's fourth quarter and the early part of the current year reinforce this confidence.

President

1965 Operations

1965 sales of products related to sewing were $534.8 million. In 1958 the comparable amount was $414.4 million. Sales of sewing products amounted to 54.6 per cent of total Company sales in 1965, whereas in 1958 they accounted for 93 per cent of the Company total.

During the same period, sales volume in products other than those related to sewing has grown through acquisitions (including Friden) and internal development from $29.9 million to $445 million or 45.4 per cent of the total as compared with only seven per cent in 1958.

In addition to household and industrial sewing machines, the major product lines of the Company today include business machines, textile machinery, instrumentation, heating and air conditioning equipment and a wide variety of household appliances. Comparative sales in 1964 and 1965, stated in terms of market served, are shown below.

	1965	1964
	(Amounts in Millions)	
PRODUCTS FOR THE HOME	$642.8	$588.0
BUSINESS MACHINE PRODUCTS	138.3	116.3
PRODUCTS FOR INDUSTRY	198.7	191.9
TOTAL	$979.8	$896.2

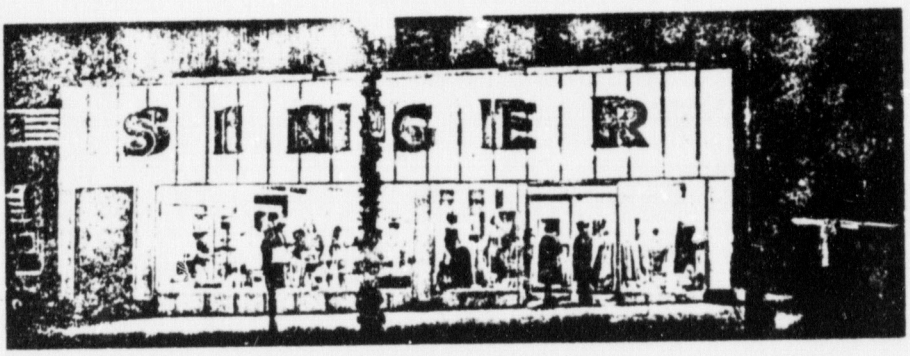
Worldwide sales of consumer products in 1965 amounted to $642.8 million or approximately 65 per cent of consolidated sales. In addition to sewing machines and related merchandise such as fabrics, patterns and notions, principal products for the home include floor-care and home entertainment equipment, refrigerators, washing machines, kitchen ranges, knitting machines and portable electric hand tools.

Sales of products for the home by geographical area were as follows:

	1965	1964
	(Amounts in Millions)	
United States	$234.4	$212.6
Europe	176.1	177.8
Latin America	94.7	73.7
Far East	75.2	70.5
Africa and the Near East	41.3	35.4
Canada	21.1	18.0
Total	$642.8	$588.0

These results represent an improvement over 1964 of ten per cent in the United States and nine per cent in the rest of the world. Sales of household sewing products totaled $454.9 million as compared with $433.3 million in 1964, an increase of five per cent. Sales of other products for the home increased 21 per cent.

This Singer Center in Auburn, New York, is the prototype for medium-sized Singer retail outlets throughout the United States.



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The Singer portable stereo phonograph has proven a favorite of Young America and is an important part of the Company's $22 million in sales of home entertainment equipment in the United States.

The "Touch & Sew" machine is the only model available which does all three kinds of stitching: straight, zig zag and chainstitch.

UNITED STATES Our consumer products business in the United States compiled a record-breaking year in 1965, with sales increasing by more than ten per cent and earnings also significantly ahead of 1964. Both manufacturing and marketing activities contributed to the improved results.

Most of our U. S. sales of products for the home are made through our network of retail outlets. At year end, 1,897 such outlets were in operation: 1,456 Company-operated Singer Centers; 52 leased departments, principally in major department stores; and 389 Singer-approved independent dealers. As part of the Company's continuing program to strengthen its distribution and improve the quality of its retail operations, 213 new outlets were opened during the year and 226 were closed.

A significant accomplishment during the year was a 14 per cent increase in unit sales of new household sewing machines. This established an all-time record high for unit sales of Singer sewing machines in the United States. The gain resulted from a broadened and improved product line, coupled with an aggressive marketing program aimed primarily at increasing the Company's penetration of the medium and low price segments of the market. At the same time, we successfully maintained our pre-eminent position at the high end of the line.

During 1965, three new "Touch & Sew" sewing machine models were introduced incorporating many additional features. Among the more important was the addition of a chainstitching capability, making these Singer machines the first and only sewing machines to do all three kinds of sewing: straight, zig-zag and chainstitch.

Our program to add fabrics to Singer outlets is continuing to expand, with 1965 fabrics volume exceeding $10 million. Further gains were made in sales of such sewing accessories as patterns, zippers, buttons and thread. In the United States some six hundred Singer shops now carry fabrics, an increase of 73 during the year. Emphasis in 1966 will continue to be placed on fabrics of better quality and variety especially loomed for Singer, and on special promotional fashion events.

Another noteworthy development during the year was the emergence of home entertainment equipment as a major consumer product line, second in importance only to sewing machines. Sales exceeded $22 million and increased by more than 33 per cent, largely attributable to the results of the KLH company in Cambridge, Massachusetts. KLH sales of superior quality sound reproduction products have tripled since the year prior to acquisition, with earnings growth more than keeping pace. Our consistent success with home entertainment equipment identifies this as an area in which future growth opportunities appear attractive.

Production at Pickens, South Carolina, of portable electric hand tools for Sears

Neapolitan street scene. Home laundry equipment and refrigerators account for about one sixth of the Company's retail sales in Europe.

In Lapland, as elsewhere in the world, the Company provides threading charts, textbooks and other teaching aids for instructors in home economics.

continued to expand. We are now making 52 different tools ranging from quarter inch drills to hedge trimmers. Upright vacuum cleaners for private label distribution are being produced in the factory at Anderson, South Carolina.

In June, agreement was reached with approximately ninety Japanese manufacturers and exporters of household sewing machines settling all outstanding claims arising from the anti-trust suit filed against the Company by the Justice Department in 1959. Five damage suits filed by companies and individuals who were not parties to the agreement are still pending. We believe that these claims will be disallowed, settled or otherwise disposed of on a basis that will not have a significantly adverse effect upon the financial position of the Company or its business.

EUROPE During 1965, there was a further slackening in the pace of economic growth in the principal European countries. The effect of this upon the market for consumer durables was particularly severe, and these conditions were compounded by price controls and credit restrictions intended to control inflation. Our sales of consumer products in Europe declined by about one per cent. Profit margins narrowed as selling and administrative costs increased as a result of the difficult market conditions, and earnings were sharply lower.

Great Britain's economy was troubled throughout the year by currency problems, rising prices, lagging productivity and mounting industrial costs. Measures adopted to restrict consumer spending had a significantly adverse effect upon the sale of merchandise through our 539 Sewing and Home Appliance Centres in the United Kingdom.

Price controls and curbs on credit in France held the economy to its lowest rate of growth in a number of years. Of special significance to our business, which is heavily dependent on instalment selling, was an increase in down payment requirements. Despite this, some improvement in sales volume was noted in the final quarter of 1965 and in the early part of 1966.

In Germany, where business conditions were generally good, our difficulties were largely internal, accentuated by a severe labor shortage. Our German marketing organization has been strengthened and our distribution is being broadened to include a larger number of independent merchants. The acquisition of Friedrich Schwab and Company, if completed, would provide additional potential for sales growth. The downward trend of our marketing business in Germany has been arrested and we are confident that it can be reversed in 1966. Karlsruhe Factory, which exports a significant portion of its household sewing machine production, had a good year. In the third quarter, it began the manufacture of a new line of automatic zig-zag sewing machines for sale throughout Europe.

The economy of Italy, which was the first major country to be affected by the current business slow-down in Europe, appeared to be regaining some momentum in the latter part of the year. Monza Factory began production late in the year of a new line of inexpensive zig-zag machines for sale in Italy and for export to many other markets. In spite of the general downward economic trend, sales of refrigerators which are now produced at our new Domowatt facility, near Turin, increased substantially. We are continuing with an expansion program at this location which will add 400,000 square feet to the present plant. Automatic washing machines will be produced at Domowatt in 1966.

In the Scandinavian countries, sales held up but profit margins were lower. The Benelux nations showed little improvement. Results in Spain and Portugal were adequate, but an inflationary trend clouds the future outlook. In Greece we had a good year, but government regulations prevented remittance of earnings.

Operations at the Company's largest plant in Clydebank, Scotland, resulted in a substantial net loss in 1965. Severe production difficulties were experienced in the second and third quarters, due in part to the failure of unions and employees to recognize the need for both increased productivity and improved quality. These difficulties reached their apex during the period when a new series of household sewing machines was being brought into production. Also at the same time production of industrial sewing machines was being realigned and expanded. By the end of 1965 production and productivity had improved somewhat and early 1966 results indicate further improvement.

The general economic outlook in Europe remains uncertain. However, through careful control of selling and administrative expenses and improved production and distribution, we expect to reverse the 1965 trend of our business in the current year.

LATIN AMERICA Sales of consumer products in Latin America were 28 per cent higher in 1965. Net income was sharply higher with all of the improvement occurring in the latter half of the year. Better economic conditions and greater currency stability in a number of countries, coupled with our stronger field organizations, were major factors in the improved results.

Sales of household sewing products, which account for two thirds of our total consumer volume in Latin America, were somewhat higher. Sales of other products for the home, such as kitchen ranges, refrigerators, television sets, knitting machines and portable typewriters, rose significantly.

Shop Manager Jesus Rodriguez of Caguas, Puerto Rico, adjusts a dressmaker's sewing machine.

A sidewalk demonstration of a home knitting machine in a suburb of Mexico City attracts an all male audience.

The Brazilian government was increasingly successful in reducing inflation, stabilizing the currency and stimulating moderate recovery from the recession of the first half of the year. As a result, our earnings improved materially. In the latter half of 1965, a new model sewing machine was introduced which had a favorable effect on operating results. The sewing machine factory in Brazil, largest of the five production facilities in Latin America, is gradually being re-equipped and a new gray iron foundry will come into operation during 1966.

In Mexico our business continued to thrive despite some hesitation in the national economy during the middle of the year. The Mexican factory is being tooled to produce more of the parts presently purchased from local suppliers. Our operations in Peru, Venezuela and the Central American republics also flourished, establishing new records for sales and earnings. Enlargement of our manufacturing capability in Colombia, largely completed during 1965, makes our ability to supply that important market more secure than in any recent year.

FAR EAST Sales of consumer products in the Far East were about $5 million higher than in 1964, due primarily to good increases in Japan, the Philippines, Thailand, India and Ceylon. Sales in Australasia decreased slightly as a result of tighter credit and increased competition. Our operations in Indonesia were placed under government control in May.

Although the Japanese economy failed to maintain its rapid growth of the past several years, our business in that country held up well, largely as a result of improvements in our product line and further expansion of our distribution network. Sales were excellent in Pakistan as well as India in the first half of 1965, but the war which began in September had an adverse effect on our results in both countries for the balance of the year.

Efforts to diversify our product lines, where appropriate, have made steady progress, with refrigerators, knitting machines and air conditioning equipment accounting for the bulk of the improvement. In the Philippines, initial distribution of small agricultural tractors has been successful.

Earnings in the Far East decreased somewhat from the level achieved in 1964, principally reflecting results in Australasia and Malaysia, and to a lesser extent, Taiwan and Indonesia. Political unrest contributed to the decline in Malaysia. Start-up costs were responsible for a loss in Taiwan, where we re-entered the market in 1964 after a lapse of 25 years. Our sewing machine factory there is now in full operation, and our sales effort is being intensified. The loss experienced in Indonesia was relatively small since nationalization had been anticipated and our operations reduced in scope.

Hong Kong, with its growing population and well established needle trades, represents a good market for sewing products.

A happy day in Los Baños, the Philippines. Most Singer sewing machines and cabinets sold in the Philippines are local products manufactured in Taytay.

District Sales Manager David Mwanzia Kimanzie visits a dressmaking class in Nairobi.

Iranian sales representative, Seyed Morteza Moniri, demonstrates the art of sewing machine embroidery.

The plants in this part of the world which import sets of parts from other Singer factories for local assembly, continued to increase indigenous content. Factories with available capacity have added new products. In the Philippines, we are now producing household and office furniture in addition to sewing machines.

In spite of unsettled political and military conditions in Southeast Asia and economic problems elsewhere, we expect our business as a whole in the Far East to improve during 1966.

AFRICA AND THE NEAR EAST The 50 nations, colonies and protectorates comprising the Africa and Near East territory present an ever-changing variety of social, economic and political situations. Fortunately, deteriorating business conditions in one area are frequently offset by improving conditions in another. Such was the case in 1965 when a drop in sales in the Sudan, Turkey and Tanzania, caused in part by civil disturbances, was more than overcome by substantially improved results in Southern and Western Africa, Ethiopia, Libya, Lebanon and the Trucial States. For the territory as a whole, sales and net income rose about 15 per cent.

Sales of household sewing products were slightly higher than in 1964. Sales of other products for the home, such as radios, phonographs, refrigerators, knitting machines and television sets, rose sharply, and accounted for 29 per cent of consumer volume.

New factories were opened at Casablanca in Morocco, where import restrictions had reduced sales, and at Nairobi in Kenya, increasing to six the number of factories in the territory. Both new plants will be operating at planned capacity by mid-1966.

CANADA Aided by favorable economic conditions, higher consumer purchasing power and an aggressive marketing program, we were successful in increasing both our sales and our share of the sewing machine market in Canada in 1965.

An important innovation during the year was the decision to undertake the marketing of home entertainment equipment, such as radios, phonographs and television sets, in most of our Canadian retail outlets. This action followed successful test marketing of this type of equipment in 1964. The addition of home entertainment equipment to our existing line of sewing machines, floor-care equipment, typewriters and small appliances, enabled us to increase sales volume per store substantially. We now operate 159 retail outlets in Canada. During the year, seven new stores were opened in major suburban shopping centers and 18 existing retail outlets were refurbished. Fabrics are being sold in 23 of the larger stores and we plan to increase this number.

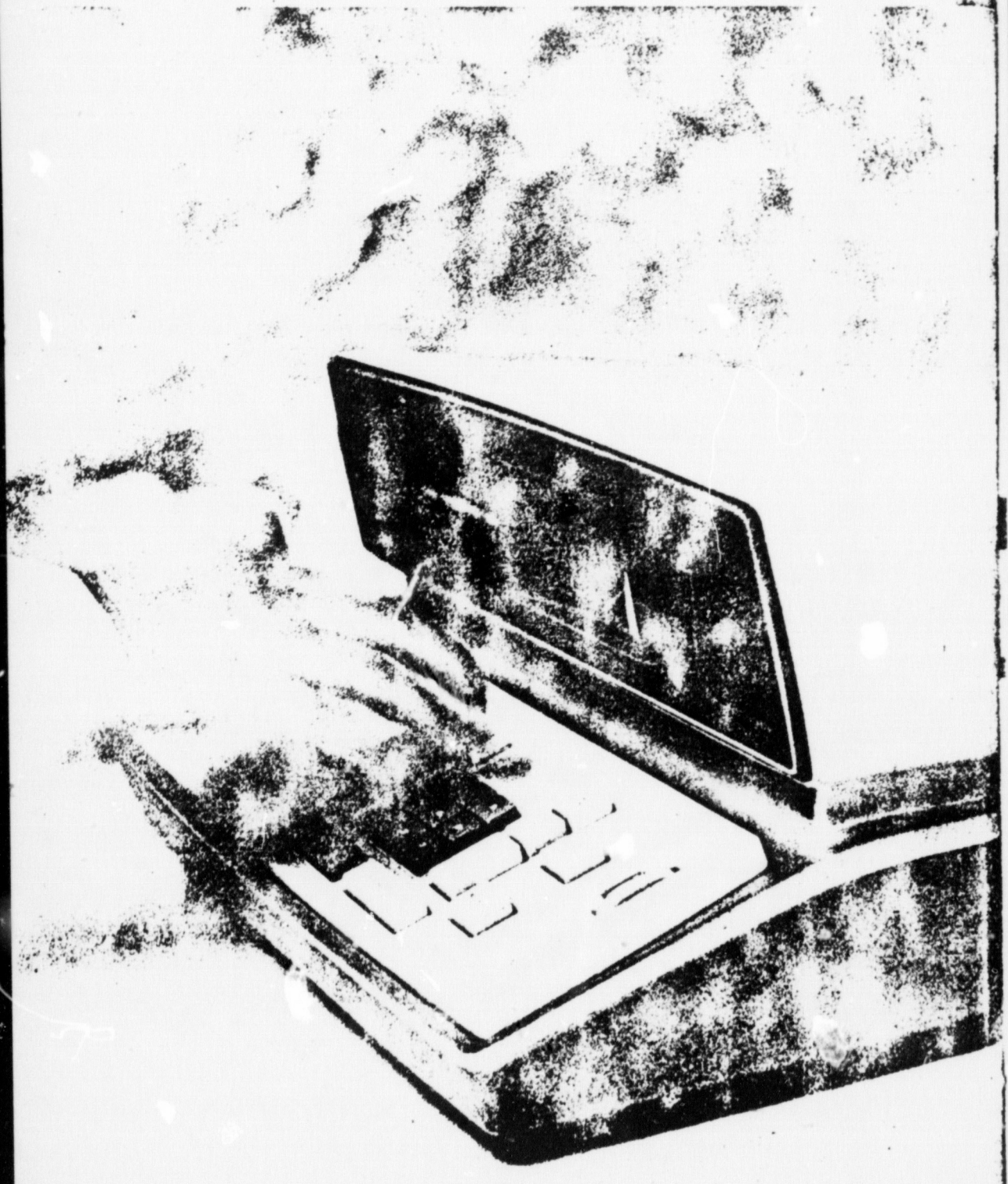
The new product lines, together with continued emphasis on our traditional sewing product business, should contribute to increased sales and earnings in 1966.

Business machines produced and sold by the Company, largely under the Friden trademark, accounted for 1965 sales of $138.3 million. This was a gain of 19 per cent and represented another record year. Business machines now amount to 14 per cent of consolidated sales. Net income also increased but by a somewhat smaller percentage due to continued high costs of introducing new products together with increased expenditures for research and development. The sales increase was well distributed both geographically and among various product lines. U. S. sales were $96.5 million, an 18 per cent increase. Sales elsewhere were $41.8 million, a gain of 22 per cent.

In 1965, data processing equipment accounted for 39 per cent of total business machine revenue; calculators and adding machines accounted for 29 per cent; and the remaining 32 per cent was in graphic arts and mailroom equipment, and in service income.

The Model 132 electronic calculator combines the speed and quietness of an electronic computer with the simple input and operational flexibility of a mechanical desk-top calculator.

The Model 2201 Flexowriter automatic writing machine with Model 2214 Selectadata selective reader is used in the preparation of business documents such as sales and purchase orders.



Sales of business machine products by geographical area were as follows:

	1965	1964
	(Amounts in Millions)	
United States	$ 96.5	$ 82.1
Europe	28.8	22.0
Other	13.0	12.2
Total	$138.3	$116.3

Highlighting 1965 operations in the business equipment field was the introduction of seven new Friden products which reflected the increased emphasis being given to research and development.

In the data processing field there were three new products:

- Model 2201 Flexowriter automatic writing machine provides greatly increased programming flexibility to meet requirements of source data automation.
- Model 5015 Computyper electronic billing/accounting machine with auxiliary tape punch offers faster, more versatile processing and expanded capability for simultaneous collection and storage of source data.
- Model 2201 data transmission network makes possible on-line data transmission between remote locations.

The adding machine and calculator group introduced four new units:

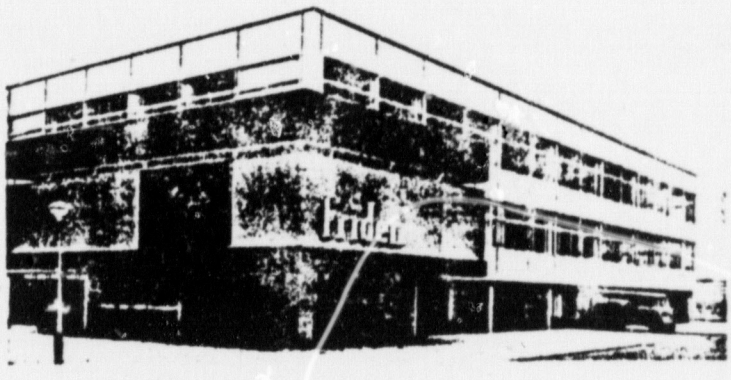
- Model EC 132 electronic calculator, a more sophisticated version of the Model EC 130 introduced in 1964, provides larger processing and storage capacity and the capability of calculating square roots automatically and instantaneously.
- Model 1901 entry counter, an optional feature for Models EC 130 and 132, gives a control count of numeric entries.
- Model SVE rotary calculator features exclusive fully automatic short-cut multiplication.
- Model 0105 adding machine has a special type style which enables the tape to be read by an optical scanning device.

Outside the United States substantial progress was made in increasing direct distribution of business machine products. We acquired the businesses of former distributors in Canada, Italy and Australia, and further efforts were made to expand the distribution of business machines through existing Singer sales organizations in Africa, the Near East, Latin America and the Far East.

Vigorous marketing efforts and emphasis on creating desirable new products should make 1966 another record year for the Company in the business machine field.

The Model 401C semi-automatic postage machine, introduced in Canada in October, stamps, seals and stacks envelopes.

Friden sales headquarters for Holland moved into this new building in Amsterdam in June.



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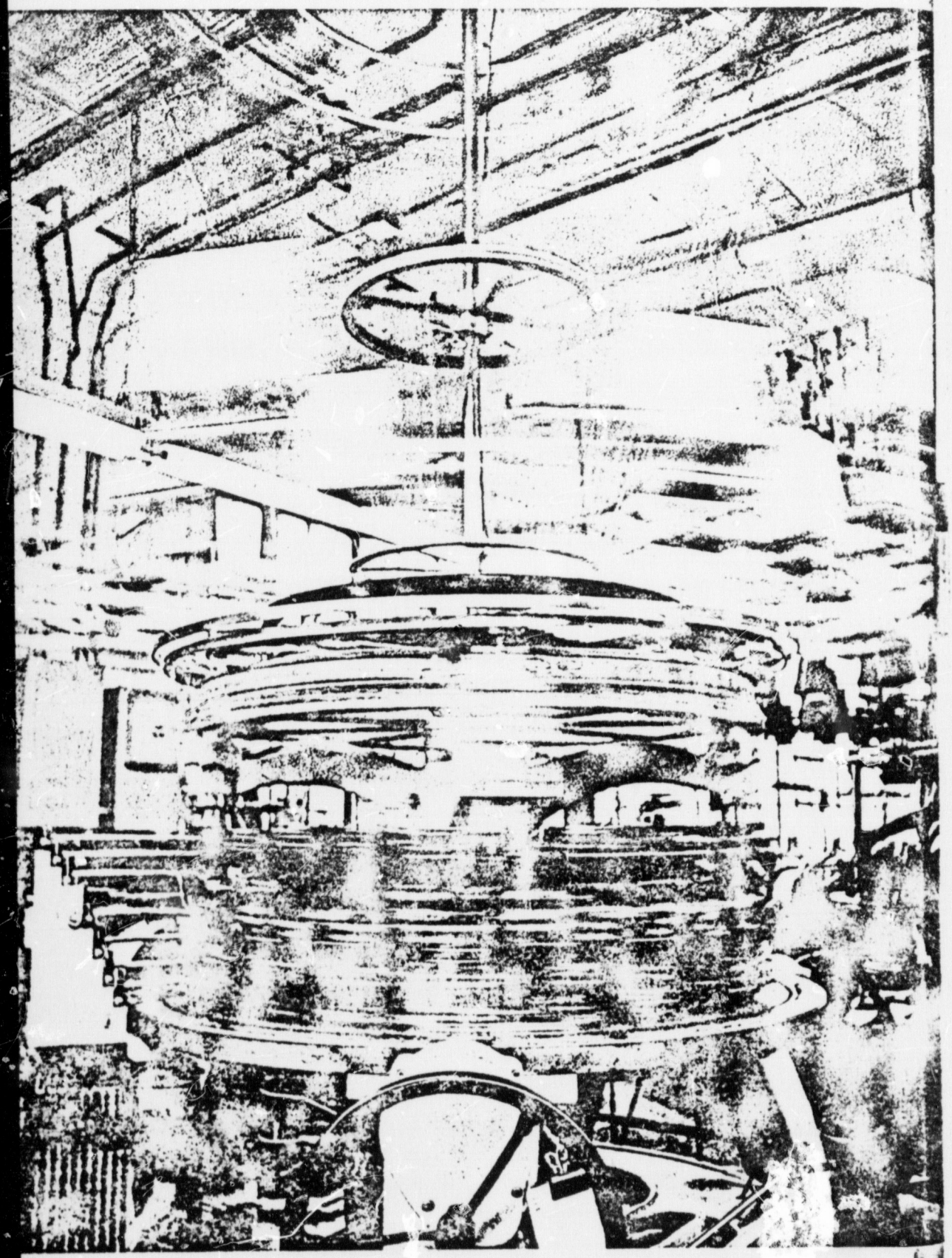

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In 1965, sales of industrial products were 12 per cent higher than in 1964, totaling $198.7 million and accounting for 20 per cent of consolidated sales. Principal industrial products are sewing machines and allied equipment, textile machinery, instrumentation, and electric heating and air conditioning equipment.

The geographical distribution of industrial products sales is as follows:

	1965	1964
	(Amounts in Millions)	
United States	$139.4	$116.7
Europe	32.2	35.6
Latin America	10.7	8.7
Far East	7.6	7.2
Canada	5.1	4.4
Africa and the Near East	3.7	4.4
Total	$198.7	$177.0

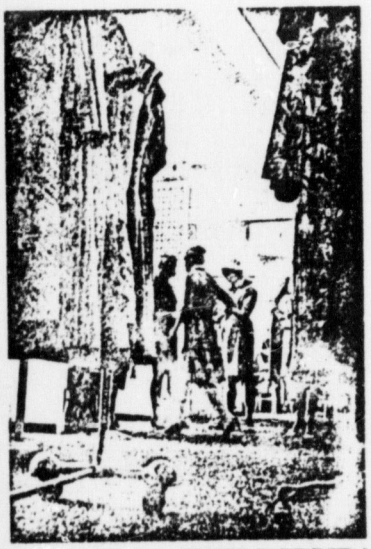
At the end of 1964 the Company disposed of its interest in Thurso Pulp and Paper Company and certain other associated properties in the Thurso area of Quebec. During 1964 these activities contributed sales of $14.9 million which, for comparative purposes, have been excluded from the 1964 amount shown above for Canada.

INDUSTRIAL SEWING EQUIPMENT Worldwide sales in the industrial sewing equipment field in 1965 were $79.9 million, approximately the same level as in the prior year. Higher volume in the United States and Latin America was offset by declines in Europe, primarily in Italy and France.

With the completion during 1965 of the transfer of industrial sewing machine production from the factory in Bridgeport, Connecticut, to plants in the United States, Scotland and Germany, significant cost improvements are expected. In addition, programs have been instituted to make our factories more responsive to market conditions. In order to reduce our costs on certain low volume machines, we are now producing three types of overedgers and a highly complex buttonhole machine at our factory in Japan.

Twenty-two new varieties of industrial sewing machines were successfully brought to market during 1965. In addition, large curing ovens for imparting a permanent shape

Singer textile machinery, such as this all purpose knitting machine, produces non woven fabrics used in the manufacture of a wide variety of apparel and household furnishings.



A showroom of David Crystal, Inc. The $30 billion U.S. apparel industry is a major user of Singer industrial sewing machines and allied equipment.

The Climate Control Division makes and sells a large number of electric heaters and heating systems under the "Electromode" trademark.

to wearing apparel were developed and marketed during the year. This gives us a firm foothold in this segment of the apparel industry which is demonstrating dynamic growth. Our garment finishing equipment was rounded out by the addition of an extensive line of Singer pressing equipment in early 1966. In addition, a new line of chain stitch machines geared to the knitwear industry will be introduced to the United States market in the Spring.

TEXTILE MACHINERY Sales of textile machinery in 1965 were almost $34 million, a 29 per cent increase over 1964, and earnings were substantially higher.

The Cobble Division, which produces tufting and textile finishing equipment, posted a 19 per cent gain in sales. A notable new product of this fast-growing division is a machine incorporating a newly patented principle known as air tufting which makes possible higher operating speeds in the manufacture of carpets.

The Fidelity Division, which produces knitting machinery used in the manufacture of hosiery, rebounded sharply from its performance of 1964. Substantial orders for Fidelity equipment were placed by several of the leading U. S. hosiery manufacturers.

The Supreme Machinery Division, which manufactures large diameter knitting machinery for the garment industry, had a successful year with a 24 per cent sales increase. Sales of Alemannia flat bed knitting equipment, produced in Germany and now distributed in the United States by the Supreme sales organization, increased slightly.

HEATING AND AIR CONDITIONING Sales in the electric heating and air conditioning fields increased by more than 20 per cent in 1965, totaling approximately $25 million. Sales of Remington air conditioning products which are installed principally in motels, hotels, hospitals, schools, apartment houses and office buildings, increased sharply.

Electric heat is now used in about two and a half million U. S. dwellings. This is an increase of nine times the number of ten years ago. Electromode, the leader in electric space heating, has participated fully in this rapidly growing market. In 1965, Electromode expanded its distribution and developed a new electric baseboard heater for introduction in 1966. Sales of freeze protection devices and specialty wire products by Easy-Heat/Wirekraft also increased.

Remington and Electromode manufacturing operations were consolidated in a newly acquired and renovated manufacturing facility in Auburn, New York, in the middle of 1965. This has permitted year-round balanced production of products contra-

seasonal in nature and is resulting in substantial reductions in manufacturing costs.

The outlook for the Company in the electric heating and air conditioning fields is especially promising in view of both the large increase forecast in the number of "all electric" homes and business structures and the growing public demand for total environmental comfort.

TECHNICAL PRODUCTS Sales of technical products, which include instrumentation, industrial controls, special purpose electrical and electronic devices, and research and development services, exceeded $42 million in 1965, an increase of 17 per cent.

The Diehl Division, which manufactures a wide variety of specialized motors, clutch brakes and servomotor components for stitching, textile and other industrial equipment, achieved sizeable profit improvement on a 15 per cent increase in sales.

Largely as a result of several substantial defense contracts, HRB-Singer, Inc., which is primarily a government contractor supplying systems management and equipment in the fields of intelligence and reconnaissance, enhanced its leadership in the field of infrared technology, and recorded a sizeable increase in sales. Of particular significance was a $15 million contract from the U. S. Army for production, over a three-year period, of airborne infrared surveillance equipment.

The Metrics Division, a large producer of electrical and electronic laboratory and field test instruments, experienced continued operating difficulties and is not yet profitable. The technical staff has been strengthened, products have been redesigned, manufacturing facilities have been rearranged and present operations are now on a more efficient footing. Operating losses have been substantially reduced and Metrics is expected to be operating profitably by the end of 1966.

Research and development expenditures by the Company in 1965 once again increased at a faster rate than sales. This investment amounted to $18 million, an increase of 14 per cent. These figures do not include $7 million for research funded by others, largely the government, nor does it include the cost of market research, long-range planning, patent protection and other activities sometimes classified as research. Research and development expenditures in 1966 are again scheduled to rise at a faster rate than sales.

At the end of the year, 15 research and development laboratories were in operation, augmented by 24 product engineering facilities at principal Singer factories. These facilities were manned by more than 2,200 scientists, engineers, technicians and supporting personnel.

In 1965, sewing machine research and development accounted for approximately half of the Company's total research investment. The Central Research Laboratory at Denville, New Jersey, is concerned primarily with the development of new concepts of stitch and seam formation applicable to both household and industrial equipment. These concepts are developed into prototypes in laboratories in Scotland, Germany and at Elizabeth, New Jersey, and ultimately into production models by product engineering groups at various sewing machine factories. As a measure of the success of this activity, it should be noted that during 1965, 12 new household models and 22 new varieties of industrial sewing machines were brought into production.

A new Friden laboratory facility was completed early in 1965 at San Leandro, California. Now in full operation, it is concentrating on the creation of concepts having application to the operation of business machines, especially in the field of data processing. This includes investigations in the fields of fluid logic, solid state physics, hydraulics and electronic-memory technology. The research capability at the Friden plant in Rochester, New York, was also expanded significantly in 1965.

Research activity in the instrumentation field encompasses the development of new techniques in precise electrical and electronic measurement and their application to improved devices for field and laboratory use. A highly specialized vortex type air cooling device which has broad application within the instrumentation and business equipment fields was developed and is now being produced by Diehl Division.

A significant development of the textile machinery research group was a machine producing single-face terrycloth by the tufting process at 20 times the speed of the conventional loom. In addition, a combination knit-stitch machine which knits and attaches ornamental trim to garments in a single operation was well received in trade circles.

HRB-Singer, Inc., which has the most advanced research capability within the Singer organization, is an acknowledged leader in infrared technology. A 1965 result of research in ultrasonics was the bringing to market of an ultrasonic yarn trimmer for hosiery machines which is presently being field-tested by the Fidelity Division. HRB is also engaged in a major long-range project related to the flow of audio information.

In addition to product-oriented research, much time and effort are devoted to the development and improvement of manufacturing techniques, processes and materials and to the application of computer logic both in product design and manufacture.

Infrared equipment developed by HRB-Singer permits aerial mapping by night or through overcast. The optical axis of the scanning system is accurate to within 0.0002 inch.

Obviously, the most important resource of the Company is its employees. Worldwide Singer employment was approximately 101,000 at year end, up 2,000 since the end of 1964. Approximately 31,000 were employed in production and 70,000 in sales and administrative work. U. S. employment was 34,000, approximately the same as in 1964.

Employing competent people, training them and giving them opportunities to develop to the limit of their abilities are basic personnel objectives of The Singer Company.

WAGES AND BENEFITS Total payments to or on behalf of employees in 1965 reached $392.7 million compared with $357.3 million in 1964. In addition to employee benefits required by law, the Company provides pensions, group insurance and other benefits

The people of Singer are of many ages, races, religions and nationalities. They manufacture, sell and service a vast number of products for many customers with many needs.

in accordance with sound industrial practice. Wages and salaries are kept competitive by continuing studies of prevailing levels of compensation in other companies. Systems of position evaluation and performance appraisal assure that wages and salaries are equitable in terms of job content and individual achievement.

The employee stock purchase plan for U. S. and Canadian employees, which was established in 1962, had 6,522 participants out of 26,217 eligible employees. Members of the plan had purchased a total of 145,575 shares by the end of 1965.

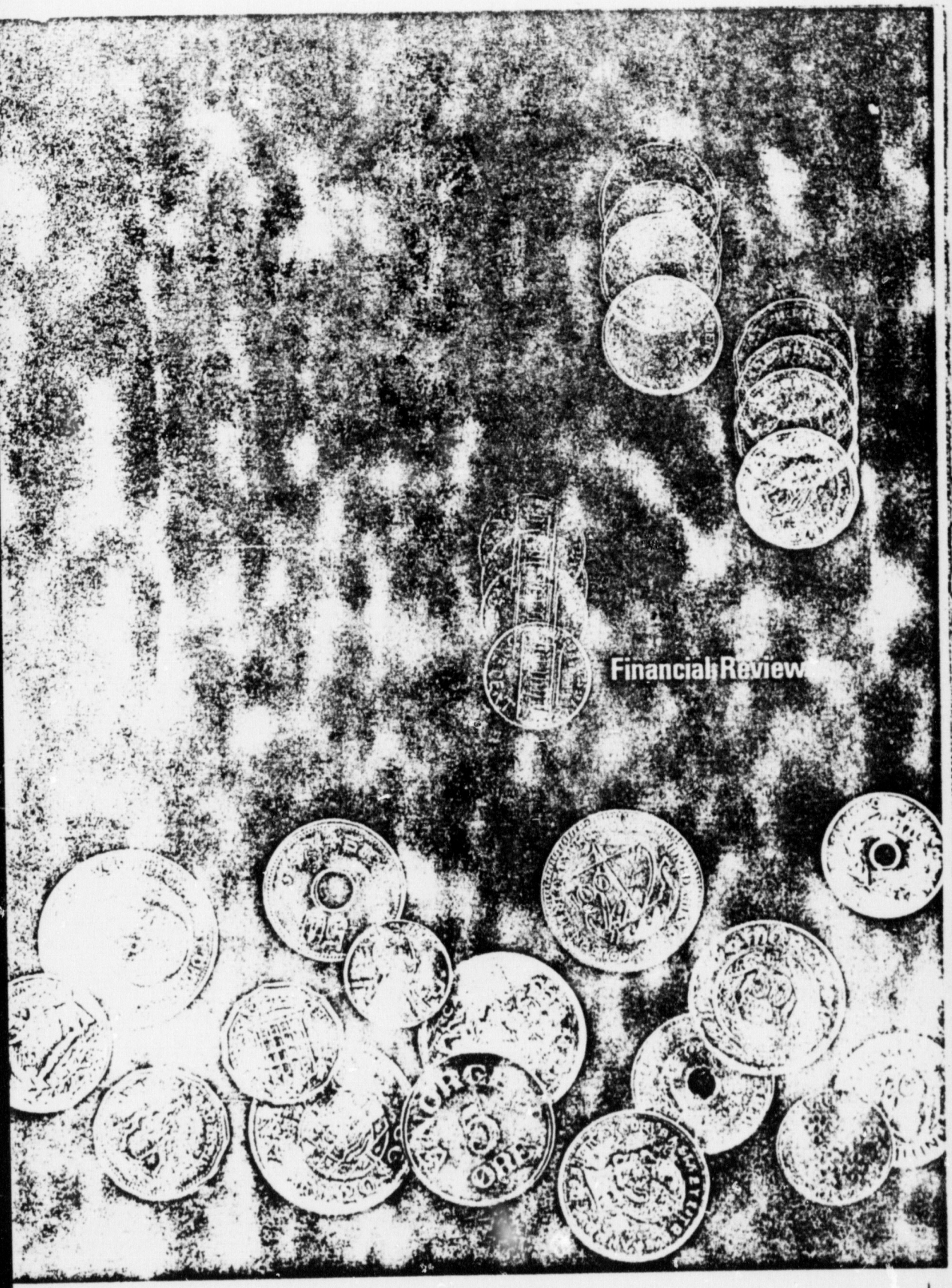
EXECUTIVE CHANGES There were an unusual number of executive changes and appointments during the year. In February, Edwin J. Graf, a Vice President of the Company, was appointed Managing Director of the Clydebank Factory. On January 1, Ralph P. Benn was named Vice President in charge of European operations succeeding Herbert Burchill who was named Vice President for Product Policy. H. Neal Karr succeeded Mr. Benn as Vice President in charge of Canadian operations.

On February 1, Dr. George A. Downsbrough joined the Company as Vice President in charge of the Technical Products Division. In April, Newton H. Hoyt, Jr., Treasurer, and Donald D. Marsden, Controller, were appointed Vice Presidents. In August Robert E. Pequignot was appointed Vice President in charge of the newly-formed Climate Control Division.

In the current year, Alan W. Drew, who had previously been in charge of the Special Products Division, was appointed President of Friden, Inc. effective February 1, succeeding Philip R. Samwell who was appointed Chairman of Friden. Mr. Samwell succeeded Walter S. Johnson who retired. Messrs. Samwell and Johnson continue to serve as Directors of The Singer Company. Charles F. Bruder, Vice President for Development, will temporarily be responsible for operations of the Special Products Division, in addition to his regular duties.

In February of 1966, Donald D. Marsden was appointed Vice President and General Manager of the Far East Division, succeeding Harold R. Crawford who will retire later this year. Andrew J. Reinhart has succeeded Mr. Marsden as Controller. Lawrence E. Hough, a Vice President of the Company, formerly in charge of the Manufacturing Division, has resigned with effect from March 31, 1966.

The rapid expansion of our business in recent years has required intensive executive development within the Company as well as the employment of many executives for important line and staff positions from outside the Company. The executive resources of the Company, of course, have also been strengthened as a result of acquisitions. Long term, we look to our present employees as our principal source of future executives and thus to the increased importance of our policy of promotion from within.


Financial Review

Financial Review

NET INCOME Net income in 1965 totaled $44.5 million which was four per cent lower than 1964's record net income of $46.5 million. Net income was $4.03 per share in 1965 compared with $4.19 in 1964, based on average shares outstanding in each year.

Earnings per share reported by quarter were as follows:

	1965	1964
First Quarter	$ .87	$1.13
Second Quarter	.94	.86
Third Quarter	.92	.98
Fourth Quarter	1.30	1.22
	$4.03	$4.19

DIVIDENDS Cash dividends paid in 1965 were $2.20 per share, an increase of 20 cents per share over the amount paid in 1964.

NET SALES Sales in 1965 totaled a record $979.8 million, and were $83.6 million or 9.3 per cent higher than 1964 net sales.

Sales of sewing products totaled $534.8 in 1965 and were 54.6 per cent of the total. In 1964, sales of these products were $513.7 million or 57.3 per cent of the total.

Sales of business machine products were $138.3 million in 1965, reflecting an increase of 18.9 per cent over 1964 sales of $116.3 million. The 1964 increase was 11.5 per cent over 1963.

Other product sales totaled $306.7 million in 1965. This represents an increase of 15.2 per cent over 1964 sales of $266.2 million.

In 1965, foreign sales were 52.0 per cent of the total, compared with 54.1 per cent in 1964. Sales in the United States increased 14.3 per cent while foreign sales increased 5.1 per cent.

Sales by major geographical area are shown in the following table:

	1965	1964
	(Amounts in Millions)	
United States	$470.3	$411.4
Europe	237.1	235.4
Latin America	110.6	85.0
Far East	87.5	84.0
Africa and the Near East	46.1	39.6
Canada	28.2	40.8
	$979.8	$896.2

In 1964 the amount for Canada includes sales of $14.9 million for Thurso Pulp and Paper Company and related operations, which were sold in December 1964.

OTHER REVENUE Revenue from sources other than sales totaled $8.5 million in 1965 as compared with $8.1 million in 1964. This revenue consisted of interest, dividends, rents, royalties and other income, as shown in the statement of income.

SALARIES, WAGES AND EMPLOYEE BENEFITS During 1965, the Company and its subsidiaries paid $392.7 million to employees directly as salaries and wages or indirectly through Company or government benefit programs. This amount includes the cost of pensions, social security taxes, workmen's compensation insurance, group life insurance, unemployment insurance, health insurance and other benefits.

TAXES The amount of income and general taxes charged to income in 1965 (excluding social benefit taxes) totaled $60.1 million. The provision for Federal and foreign income taxes reflects the reduction to 48 per cent in the U.S. Corporate rate.

WORKING CAPITAL Working capital decreased in 1965 by $2.4 million compared with an increase of $24.3 million in 1964, as shown in the following table:

	1965	1964
	(Amounts in Millions)	
Funds were derived from:		
Net income before deducting depreciation and amortization which do not require a current outlay of funds	$ 70.2	$ 72.2
Extraordinary sales of properties	—	30.6
	70.2	102.8
Funds were used for:		
Dividends to shareholders	24.3	22.2
Net additions to property, plant and equipment	35.2	38.1
Purchases less sales of treasury stock	10.3	6.3
Net change in other non-current assets and non-current liabilities	2.8	11.9
	72.6	78.5
Net (decrease) increase in working capital for year	(2.4)	24.3
Working capital at beginning of year	356.7	332.4
Working capital at end of year	$354.3	$356.7

Cash and marketable securities decreased by $4.7 million in 1965. Net accounts receivable increased $30.8 million mainly reflecting an increase in instalment sales. The amounts shown on the balance sheets are after deducting unearned carrying charges and allowances for doubtful accounts. These deductions totaled $66.3 million in 1965 and $56.1 million in 1964.

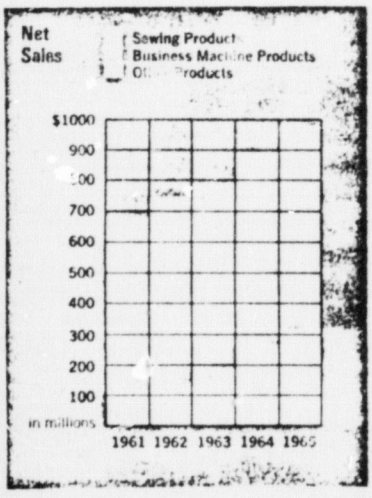
Inventories, which increased $9.3 million or 3.5 per cent, are summarized in the following table:

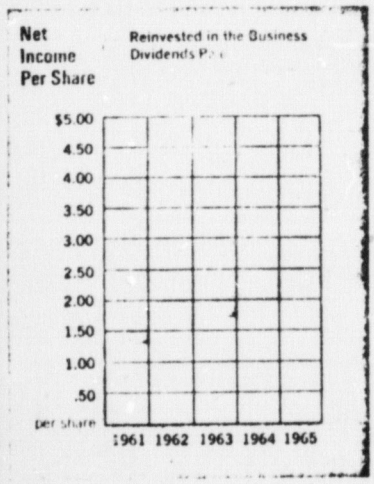
	1965	1964
	(Amounts in Millions)	
Finished goods	$174.9	$166.2
Work in process	80.9	80.4
Raw materials and supplies	22.9	22.8
	$278.7	$269.4

Current liabilities increased $37.9 million over 1964. Loans and overdrafts, principally from foreign banks, increased $40.9 million and the liability for Federal and foreign taxes decreased $4.5 million.

FOREIGN NET ASSETS Total net assets located outside the United States are expressed in U. S. dollars at appropriate exchange rates. The following table shows foreign net assets at December 31, 1965 and 1964 by major geographical area:

	1965	1964
	(Amounts in Millions)	
Europe	$124.4	$113.0
Latin America	66.9	61.4
Far East	49.2	38.0
Africa and the Near East	24.9	20.9
Canada	16.8	15.0
	$282.2	$250.3





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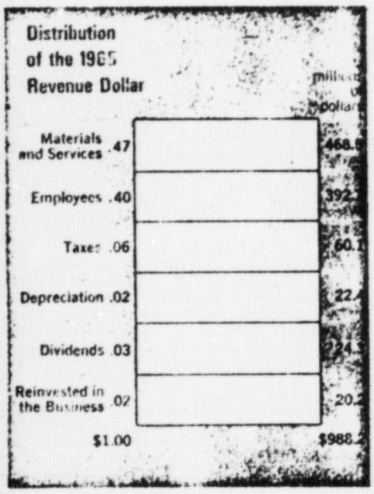


PROPERTY, PLANT AND EQUIPMENT The balances at December 31, 1965 and 1964 were:

	1965	1964
	(Amounts in Millions)	
Property, plant and equipment:		
Land	$ 13.1	$ 13.5
Buildings, less accumulated depreciation of $47.6, 1965 and $46.4, 1964	40.9	38.1
Machinery and equipment, less accumulated depreciation of $139.9, 1965 and $129.9, 1964	95.6	83.6
Construction in progress	5.8	7.4
	$155.4	$142.6

Gross additions in 1965, principally machinery and equipment, amounted to $39.7 million. Disposals of property, plant and equipment (net of accumulated depreciation) amounted to $4.5 million.

The provision for depreciation in 1965 was $22.4 million compared with $23.0 million in 1964. The decrease is due primarily to the disposal late in 1964 of Thurso Pulp and Paper Co. and related properties.

OTHER ASSETS Other assets at December 31, 1965 and 1964 were as follows:

	1965	1964
	(Amounts in Millions)	
Deposits	$ 7.6	$ 11.9
Deferred charges	7.6	9.5
Intangibles, less amortization	10.2	10.6
Prepaid expenses	7.9	7.6
Mortgages and other	12.6	13.0
	$ 45.9	$ 52.6

Deposits were mainly in foreign countries to secure currency transactions.

LONG-TERM DEBT Long-term debt, less amounts due within one year, consisted principally of unsecured promissory notes requiring payments each year to maturity. The amounts due within one year, $5.5 million at December 31, 1965 and $6.0 million at December 31, 1964, are included in current liabilities.

Interest Rates	Maturities	1965	1964
		(Amounts in Millions)	
3¼%-3⅜%	1977	$ 24.3	$ 25.5
4½%-6½%	1967	4.2	5.6
5%	1973	2.4	2.8
5%-5¼%	1971	2.1	2.6
5½%	1967	5.0	3.0
Other		10.2	8.9
		$ 48.2	$ 48.4

CAPITAL STOCK At December 31, 1965, there were 10,958,490 shares outstanding compared with 11,092,542 at December 31, 1964. On February 7, 1966 the Company purchased 200,000 shares of its stock from a substantial institutional shareholder. At March 11, 1966, the number of shares held in the treasury was 567,935.

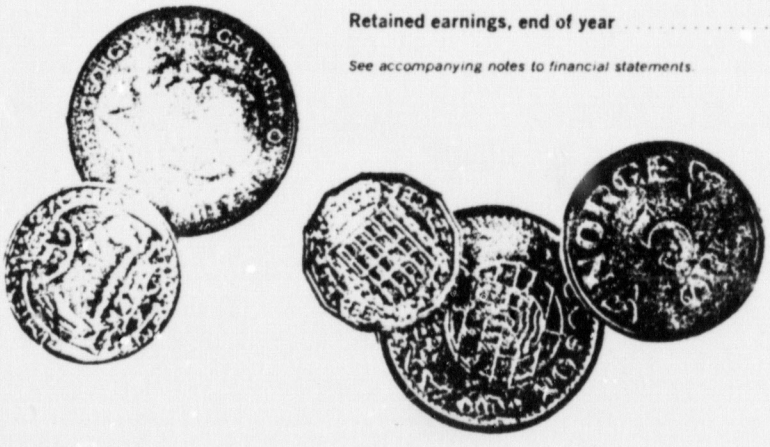
Consolidated Statements of Income and Retained Earnings

For the Years Ended December 31, 1965 and 1964

INCOME	1965	1964
	(Amounts in Thousands)	
Revenue:		
Net sales	**$979,757**	$896,239
Interest and dividends	**3,049**	2,864
Rents and royalties	**1,667**	1,539
Other income	**3,759**	3,717
	988,232	904,359
Costs and expenses:		
Costs and other operating charges	**523,803**	471,082
Selling and administrative expenses	**375,478**	342,505
Interest	**14,395**	11,599
Provision for Federal and foreign income taxes	**30,060**	32,679
	943,736	857,865
NET INCOME	**44,496**	46,494
Extraordinary income	**—**	6,337
Net income and extraordinary income	**$ 44,496**	$ 52,831

RETAINED EARNINGS	1965	1964
	(Amounts in Thousands)	
Retained earnings, beginning of year	**$325,655**	$300,531
Add net income and extraordinary income	**44,496**	52,831
	370,151	353,362
Less: Dividends paid	**24,313**	22,174
Cost of treasury stock in excess of:		
Proceeds of sales to employees	**2,419**	2,946
Net assets of pooled company	**—**	2,587
	26,732	27,707
Retained earnings, end of year	**$343,419**	$325,655

See accompanying notes to financial statements.



Consolidated Balance Sheets

December 31, 1965 and 1964

ASSETS	1965	1964
	(Amounts in Thousands)	
Current assets:		
Cash	$ 25,132	$ 25,068
Marketable securities	26,491	31,217
Accounts receivable—net	342,694	311,907
Inventories	278,744	269,401
Total current assets	673,061	637,593
Investments in and advances to affiliated companies	16,621	11,184
Property, plant and equipment—net	155,400	142,554
Other assets	45,898	52,572
	$890,980	$843,903

LIABILITIES AND SHAREHOLDERS' EQUITY		
Current liabilities:		
Accounts payable and accrued expenses	$ 86,191	$ 84,627
Loans and overdrafts (principally foreign banks)	163,503	122,601
Federal and foreign income taxes	69,116	73,640
Total current liabilities	318,810	280,868
Long-term debt	48,199	48,371
Other non-current liabilities	17,768	18,310
Reserves for realization of foreign assets and for insurance	70,000	70,000
	454,777	417,549
Shareholders' equity:		
Capital stock—par value $10 per share: Authorized 15,000,000 shares; issued 11,233,715 shares	112,337	112,337
Retained earnings	343,419	325,655
	455,756	437,992
Less: Cost of capital stock in treasury (275,225 shares in 1965; 141,173 shares in 1964)	19,553	11,638
Total shareholders' equity	436,203	426,354
	$890,980	$843,903

See accompanying notes to financial statements.

PRINCIPLES OF CONSOLIDATION The accompanying financial statements include the results of all subsidiaries. Investments in three wholly owned finance companies are included at their equity value. Investments in two small affiliated companies (47 and 22 per cent owned) are stated at cost.

EXTRAORDINARY INCOME The extraordinary income in 1964 is stated net of taxes and resulted from the sale of timberlands, a pulp mill and other properties.

FINANCE COMPANIES Balance sheets of the three finance companies at December 31, 1965 and 1964 are summarized below:

	1965	1964
	(Amounts in Thousands)	
Instalment accounts receivable	$67,057	$35,980
Cash and other assets	2,755	1,785
	$69,812	$37,765
Notes payable—unsecured	$53,739	$26,130
Other liabilities	478	587
Payables to affiliates	6,667	2,694
Equity	8,928	8,354
	$69,812	$37,765

Net income of these companies totaled $882,000 in 1965 and $824,000 in 1964. These amounts are included in other income.

FOREIGN NET ASSETS Total net assets located outside the United States at December 31, 1965 amounted to $282,200,000. These assets are shown by geographical area in the Financial Review.

INVENTORIES Inventories are stated at the lower of cost, exclusive of certain indirect manufacturing expenses, or market.

PROPERTY, PLANT AND EQUIPMENT These assets are stated at cost, less accumulated depreciation, and are shown by category in the Financial Review.

FEDERAL AND FOREIGN INCOME TAXES Income tax liabilities include amounts shown in prior annual reports as Deferred Federal and foreign income taxes. These relate principally to instalment sales.

CAPITAL STOCK OPTIONS The Company has both a qualified stock option plan and a stock purchase plan. Under the qualified stock option plan adopted in 1959, options to purchase shares of capital stock of the Company may be granted to executive employees at prices not less than market value on the dates of grant. Options granted in 1964 and 1965 expire in five years; prior options generally expire in ten years. Under the stock purchase plan adopted in 1962, employees are granted options to purchase capital stock of the Company by payroll deduction. The option price is 85 per cent of either the market value at date of grant or the market value at date of exercise, whichever is lower.

The following table shows the changes for the year in options outstanding:

	Shares	Option Prices
Options outstanding at January 1, 1965	228,492	$27.00-96.13
Options granted	125,895	48.25-82.38
	354,387	
Less:		
Options exercised	93,329	27.00-70.50
Options terminated	26,785	28.38-96.13
	120,114	
Options outstanding at December 31, 1965	234,273	27.00-96.13

Shares available for options at January 1, 1965 were 368,930 and at December 31, 1965 were 269,820.

EMPLOYEE RETIREMENT PLANS Contributions by the Company and its subsidiaries under funded Retirement Plans amounted to $3,500,000 for 1965 and $3,100,000 for 1964, including amounts for past service benefits. At December 31, 1965, the liability for past service benefits under these plans to be funded in future years is $5,600,000.

COMMITMENTS The Company and its subsidiaries are lessees under 2,800 leases expiring subsequent to December 31, 1968 with minimum rentals of $11,600,000 annually. Substantially all of the leases are rental contracts and not financing agreements.

Report of Independent Public Accountants

PEAT, MARWICK, MITCHELL & Co.
CERTIFIED PUBLIC ACCOUNTANTS
SEVENTY FIVE STREET
NEW YORK, NEW YORK 10005

To the Shareholders and
Board of Directors of The Singer Company:

We have examined the consolidated balance sheet of The Singer Company and consolidated subsidiaries as of December 31, 1965 and the related statements of income and retained earnings for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying financial statements present fairly the financial position of The Singer Company and consolidated subsidiaries at December 31, 1965 and the results of their operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Peat, Marwick, Mitchell & Co.

March 15, 1966

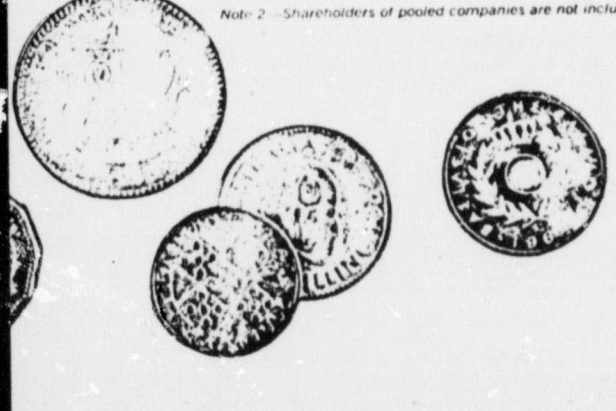
EARNINGS (Amounts in Thousands)	**1965**	1964	1963	1962	1961
Net sales	**$979,757**	$896,239	$790,188	$743,988	$682,796
Total revenue	**988,232**	904,359	800,082	751,595	689,540
Costs and other operating charges	**523,803**	471,082	403,832	376,008	352,489
Selling and administrative expenses	**375,478**	342,505	307,783	293,550	270,774
Interest expense	**14,395**	11,599	9,300	9,213	8,630
Income taxes	**30,060**	32,679	37,624	37,265	29,523
Net income	**44,496**	46,494	41,543	35,559	28,124
Extraordinary income	**—**	6,337	—	**5,327**	—

FINANCIAL POSITION (Amounts in Thousands)					
Working capital	**354,251**	356,725	332,381	342,079	332,494
Cash and marketable securities	**51,623**	56,285	63,896	80,808	73,239
Accounts receivable—net	**342,694**	311,907	264,759	243,630	223,976
Inventories	**278,744**	269,401	233,762	212,717	212,244
Property, plant and equipment—net	**155,400**	142,554	151,769	144,185	144,567
Long-term debt	**48,199**	48,371	49,095	52,770	54,559
Retained earnings	**343,419**	325,655	300,531	284,052	265,543
Shareholders' equity	**436,203**	426,354	402,025	391,752	374,490

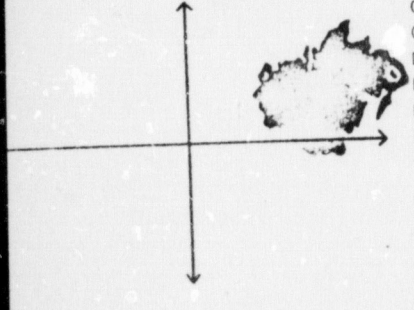
OTHER DATA					
Per share of capital stock:					
Net income	**4.03**	4.19	3.75	3.20	2.53
Extraordinary income	**—**	.57	—	.48	—
Dividends paid *(Note 1)*	**2.20**	2.00	1.70	1.55	1.30
Shareholders' equity	**39.50**	38.42	36.29	35.26	33.64
Current ratio	**2.1**	2.3	2.4	2.8	2.9
Number of shareholders *(Note 2)*	**32,323**	27,971	22,252	11,406	12,030

Note 1—Dividends paid by Friden, Inc. prior to the 1963 merger are not reflected.

Note 2—Shareholders of pooled companies are not included prior to year of merger.



Manufacturing and Research Facilities



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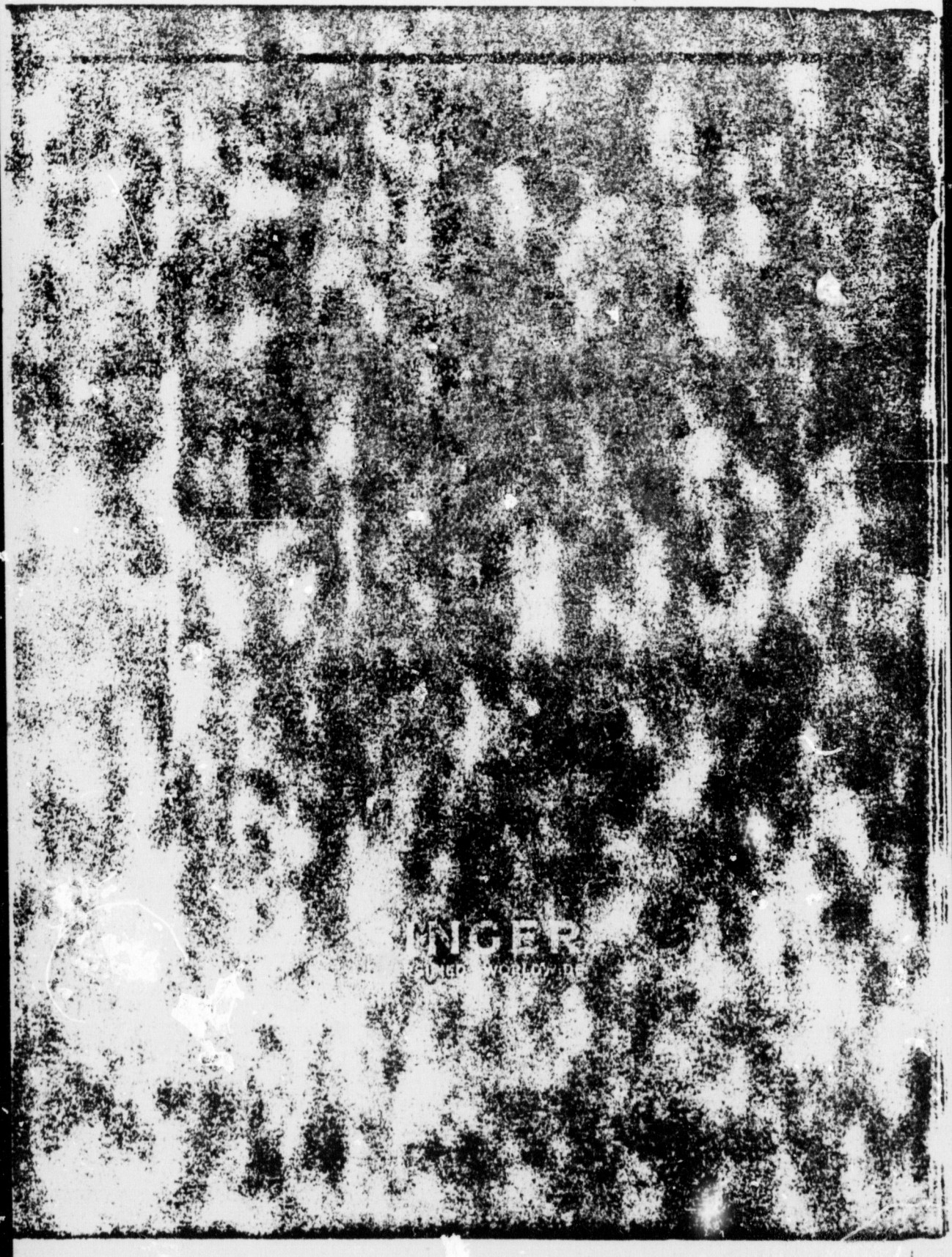

PLAINTIFF'S EXHIBIT 147

DATE 11-30-64
TIME

THE SINGER COMPANY
EXPERIMENTAL AND TEST
DATA SHEET

PART NO. ANTI-SKID DEVICE
DEPT. 195 17-42031
ENGINEER A. KALINOWSKI

TEST EQUIP. NO. 1962 - CHEVROLET CAR (CONVENTIONAL SHIFT) PR
DESCRIPTION ANTI-SKID DEVICE UNIT (COMPLETE)

CL	HYDRAULIC PRESS. AFTER VAC	CONDITION OF ROAD	SPEED	METHOD OF BRAKING	UNIT OF APPLICATION	RESPONSE
1	600	DRY-MACADAM	50/60	BRAKE-IN	NORMAL	
				CLUTCH-IN	RESPONSE	
2	625	DRY-MACADAM	50/60	BRAKE-IN	NORMAL	
				CLUTCH-IN	RESPONSE	
3	600	DRY-MACADAM	50/60	BRAKE-IN	NORMAL	
				CLUTCH-IN	RESPONSE	
4	600	DRY-MACADAM	50/60	BRAKE-IN	NORMAL	
				CLUTCH-IN	RESPONSE	
5	600	DIRT-DRY	45/50	BRAKE-IN	NORMAL	
				CLUTCH-IN	RESPONSE	
6	625	DIRT-DRY	45/50	BRAKE-IN	NORMAL	
				CLUTCH-IN	RESPONSE	
7	625	DIRT-DRY	45/50	BRAKE-IN	NORMAL	
				CLUTCH-IN	RESPONSE	
8	600	DIRT-DRY	45/50	BRAKE-IN	NO	
				CLUTCH-IN	RESPONSE	
9	600	DIRT-DRY	45/50	BRAKE-IN	NORMAL	
				CLUTCH-IN	RESPONSE	
10	600	DIRT-DRY	45/60	BRAKE-IN	NORMAL	
				CLUTCH-IN	RESPONSE	
11	600	DIRT-DRY	45/50	BRAKE-IN	NO	
				CLUTCH-OUT	RESPONSE	
12	600	DIRT-DRY	45/50	BRAKE-IN	NO	
				CLUTCH-OUT	RESPONSE	
13	600	DIRT-DRY	45/50	BRAKE-IN	NO	
				CLUTCH-OUT	RESPONSE	
14	625	DIRT-DRY	45/50	BRAKE-IN	NO	
				CLUTCH-OUT	RESPONSE	
15						

REMARKS: PERMA-VAC UNIT USED IN CAR WAS PRESSED AT 600 PSI IN TEST STAND 11/30/64

PLAINTIFF'S EXHIBIT 150

MAIL ROOM NOV 2 1964 PATENT OFFICE

This is a continuation-in-part of applicant's copending application Serial No. 322,716, filed November 12, 1963, and entitled BRAKING SYSTEM AND ANTI-SKID MEANS THEREFOR.

The present invention relates generally to braking systems for automotive vehicles and the like and is particularly concerned with the provision of novel and improved anti-skid means.

It is well known that a skid condition may be encountered by a moving vehicle where the brakes of the vehicle are applied so hard that the vehicle wheels tend to lock. Quite obviously, other factors effect the commencement and existence of a skid condition, such as the condition of the surface on which the vehicle is moving, the speed at which the vehicle is traveling, etc. However, it is possible for a vehicle to commence a skid even where the surface on which the vehicle is traveling is not wet or icy and even where the vehicle is traveling at moderate speeds, if the vehicle brakes are applied too hard. Since all control of a vehicle is lost while the vehicle is in a skid, thus increasing the danger of serious accident and personal injury, it is obviously highly desirable to prevent or reduce skidding while at the same time enabling the vehicle to come to a complete stop as quickly as possible.

It is therefore a primary object of the present invention to provide an improved braking system wherein operation of the brakes is under control of the vehicle

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RECEIVED NOV 2 1964 PATENT OFFICE

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It is therefore a primary object of the present invention to provide an improved braking system wherein operation of the brakes is under control of the vehicle

operator until a skid condition commences to exist, at which time anti-skid means automatically take over complete control of the brakes and maintain said control until danger of skidding no longer exists, whereupon the brakes are returned to normal control by the operator.

Another object of my invention is the provision of efficient and sensitive control means for the various operations of the system, which have usefulness in other types of systems as well.

Another object of my invention is the provision of novel and improved anti-skid means equally adaptable to so-called power brakes, as well as nonpower brakes.

A further object of my invention is the provision of anti-skid means of the character described wherein the vacuum system of the vehicle is utilized, but wherein the loss of vacuum in no way interferes with control of the vehicle brakes by the operator.

A further object of my invention is the provision of anti-skid means that is readily and easily adaptable to existing vehicles.

Another object is the provision of a novel and improved reverse cut-off switch that automatically renders the anti-skid means inoperative when the vehicle moves in reverse.

Still another object of my invention is the provision of an anti-skid system for automotive vehicles and the like having means which are durable and effective in

operation and which are feasible and practical both from an economic and manufacturing standpoint.

Other objects, features and advantages of my invention will become apparent as the description thereof proceeds when considered in connection with the accompanying illustrative drawings.

In the drawings which illustrate the best mode presently contemplated for carrying out the present invention:

Fig. 1 is a diagrammatic view, in perspective, of the assembly utilized in my nonpower unit, with portions being broken away for purposes of illustrat ;

Fig. 2 is an elevational view, in section, of a portion of the overall assembly illustrated in Fig. 1;

Fig. 3 is an enlarged fragmentary sectional elevation of a portion of the brake-actuating means illustrated in Fig. 1;

Fig. 4 is an enlarged fragmentary sectional elevation illustrating certain details of the anti-skid unit and the drive means therefor;

Fig. 5 is an enlarged sectional elevation of the cam gear and solenoid-actuating switch which form a part of the anti-skid unit;

Fig. 5A is an enlarged fragmentary perspective view of the cam gear;

Fig. 6 is an enlarged section taken on line 6-6 of Fig. 2;

Fig. 7 is a diagrammatic view, in perspective, of my anti-skid mears in combination with a power brake unit, portions being broken away for purposes of illustration;

Fig. 8 is an elevational view, in section, of the power brake assembly illustrated in Fig. 7;

Fig. 9 is an enlarged fragmentary sectional elevation illustrating certain details of the anti-skid means and the reverse cut-off switch in combination therewith;

Fig. 10 is an enlarged fragmentary sectional elevation of the reverse cut-off switch per se;

Fig. 11 is a fragmentary section taken on line 11-11 of Fig. 9; and

Fig. 12 is an enlarged exploded perspective view of the reverse cut-off switch per se.

According to one aspect of my invention, a sensing means for sensing when a skid condition begins is caused to activate a wheel speed-sensitive device that takes over control of the brake pressure until the skid condition ends. Advantageously, the sensing means is an inertia-responsive means that senses

a sudden change in the speed of rotation of a wheel at the commencement of skid condition. This inertia-responsive device does not control the brake pressure itself by repeated action during the skid condition, as has been attempted by the prior art. Instead the control of the brake pressure is taken over completely by a governor driven dependently with the wheel, advantageously a mechanical governor. The governor then controls the brake pressure in a hunting or modulating manner, for an extended period, until such control of the brakes is ended by a reset means that responds to slowing of the vehicle to a predetermined speed. Preferably, the reset means is a brake-pressure-sensitive device which senses reduction of brake pressure to a predetermined level which the governor can produce only when it slows to the predetermined speed.

This separation of the initiating and controlling functions is an extremely important feature. The initiating device must necessarily have a restraint to prevent operation when the vehicle merely decelerates normally. I have realized that such a restraint prevents the device from being able to effectively regulate the brake pressure due to lack of sensitivity. The governor, after it takes over control, is free of such restraint and therefore can have much greater sensitivity with the result that the brake pressure can be much more accurately regulated.

The reset device is also of critical importance because at low speeds, e.g., below 10 m.p.h., the governor forces can become so diminished that the governor can behave entirely as if

the vehicle were skidding, though not, thereby totally relieving the brake pressure. The reset device can act before this occurs, whereby normal control is regained.

A further aspect of my invention concerns the realization that a predetermined level of brake pressure, e.g., the minimum brake pressure at which skidding of the vehicle will occur on ice, generally between 100-150 p.s.i. for conventional automobiles, can be utilized to determine the setting for the brake pressure-sensitive reset device. Thereby, only at the time when skidding is no longer possible will control be taken away from the anti-skid unit to return the brake system to normal operation. This pressure-sensitive device, particularly when taking the form of a brake fluid pressure-sensitive switch, is useful with anti-skid systems generally, though of particular usefulness in the system described above.

Advantageously, the brake pressure-sensitive switch operates an electrical system, preferably a solenoid, to restore normal brake operation, and it can be employed to bring the anti-skid unit into readiness whenever the operator applies his brakes, as well as to stop the anti-skid unit from acting when skid conditions have ended.

Another aspect of the invention concerns the control of the governor. In normal operation of the brakes, the governor is prevented from influencing the brakes, but once activated, e.g., by the inertia-sensitive device, it is made continually to act, even when the vehicle wheel speeds up after the brakes have been initially relieved. A controlling or restraining member,

preferably a solenoid, is employed to achieve this operation, with the controlling member held steadily from interfering with the governor until the reset device operates. In the case where a rotary weight mechanical governor is employed, a plunger can normally restrain the governor and a solenoid, initially under the control of the inertia-responsive device, can pull back the plunger to free the governor, whereupon the plunger can operate a switch to maintain the solenoid energized, and at the end of skid conditions the reset device can de-energize the solenoid to once again restrain the governor.

Another aspect of the invention is a fluid valving system that responds to the governor to increase and decrease brake pressure. Advantageously, the valve, discharging to a brake control conduit, is moved by the governor alternately between two positions to connect two passages for fluid at different pressures to the conduit. This causes the brake pressure to rapidly vary in a modulating or hunting manner, to keep the brake pressure at maximum values while preventing skidding. The mean about which the pressure modulates changes as the slipperiness of the road changes, due to the effect such road changes have upon the governor.

For use in a closed-circuit hydraulic system, the direct control of the brakes is achieved, according to the invention, by an isolation valve that continually seals the wheel brake from the control of the operator, and a variable volume chamber, e.g., piston and cylinder, for relieving and reapplying brake pressure to the wheel, the piston modulating about a mean determined by

the modulating pressure conditions of the brake control conduit. Advantageously, the piston, at the position where it allows full pressure, can operate the isolation valve. Then the piston being spring loaded to that position can also perform a pressure-limiting function, limiting brake pressure to, e.g., 1,000 p.s.i., though the operator is capable of applying twice that much. In normal operation the brakes function as well at 1,000 p.s.i. as above, and by so limiting the brake pressure, less pressure is present to be relieved when a skid occurs, which enables faster action and allows the relief chamber to be smaller.

In other brake systems the brake control conduit can control a power unit, or in the case of air brakes, it can directly control the brake actuators associated with the wheels.

Furthermore, according to the invention, I have provided advantageous and improved constructions of the various operating components and sub-systems which can best be described with reference to the drawings.

Referring now to the drawings, and more particularly to Figs. 1-6 thereof, a closed hydraulic circuit braking system employing my novel and improved anti-skid means in combination with a so-called nonpower brake will be described. The over-all system, generally designated as 10, comprises brake pedal 12, master cylinder 14, brake-relieving device 16, hydraulic pressure switch 18, relief actuator means 20, conduit valve means 22, skid-sensing and control means 24, and anti-skid unit drive means 26.

Referring to Figs. 1 and 2, the brake pedal 12 is of conventional construction and comprises bell crank 28 pivotally connected to a suitable support on the vehicle (not shown) at 30 whereupon depression of pedal 12 causes bell crank 28 to rotate in a counterclockwise direction around pivot point 30, thus actuating connecting rod 32 pivotally connected to bell crank 28, as at 34. Rod 32 carries at its other extremity a piston 36 which functions to pump oil or other suitable fluid from master cylinder 14, all in a well-known manner. Specifically, master cylinder 14 has an upper reservoir 38 which communicates with lower chamber 40 by means of opening 42 whereupon a full supply of oil is always present in the chamber 40 to be pumped by actuation of pedal 12 and piston 36.

Fluid pumped from master cylinder 14 passes through a conduit 44 connected at one of its extremities by suitable couplings 46, 48 to chamber 40 of master cylinder 14 and at its other extremity by a suitable coupling 50 to the brake-relieving device generally designated at 16, which incorporates an isolation valve. More specifically, coupling 50 is connected to a second coupling 52 which is threadedly attached to block 54, said block having a bore 56 extending longitudinally therethrough into communication with aligned longitudinally extending bores 58 and 60 in couplings 52 and 50, respectively.

As will be seen most clearly in Figs. 2 and 3, coupling 52 is provided with an internal shoulder for receiving positioning spring 62 which positions isolation valve ball 64 adjacent valve seat 66, tending to close with slight force the bore or passage-

way 56. During normal operation of the vehicle, ball 64 is maintained in its unseated position, as illustrated in Figs. 2 and 3, against the action of spring 62, by means of spring-loaded actuator piston 68 having a reduced extension 70 in engagement with ball 64. Suitable O-rings or the like 72 are provided to insure a tight sliding fit between piston 68 and bore 56 whereby said piston effectively blocks further flow of fluid through bore 56.

Block 54 is provided with a pair of oppositely disposed passageways 74 and 76, it being noted that said passageways communicate with bore 56 just behind valve seat 66, whereupon when ball 64 is in its closed position in engagement with valve seat 66, fluid in conduit 44 from the master cylinder will be blocked before reaching the passageway 74 and 76. Passageway 74 communicates with hydraulic pressure reset switch 18 for reasons hereinafter to be described, while passageway 76 communicates by means of suitable couplings with conduit 78, which in turn communicates with the hydraulic brake lines 80 leading to the wheel hydraulic actuator cylinders (not shown) of the vehicle to actuate the brakes in well-known fashion. Thus it will be seen that with the parts in the positions illustrated in Figs. 2 and 3, and particularly with piston 68 in the position illustrated, brake pedal 12 controls actuation of the vehicle brakes through a direct line. This is the normal operating condition of the vehicle.

The actuator for the relieving device 16, generally designated at 20 (Figs. 1, 2) controls the movement of piston 68

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and hence ball 64. This actuator comprises a housing or cylinder 82 having a large piston 84 slidably mounted therein, said piston having suitable seals 86 at its outer periphery to insure that the piston 84 will make a tight sliding fit within cylinder 82 whereby no leakage will exist around the piston. Piston 84 is threadedly connected, as at 88, to the aforementioned small hydraulic piston 68, whereupon movement of large piston 84 causes corresponding movement of piston 68. Housing 82 is secured to block 54 by any suitable means, such as screws 90, and the adjacent end wall 92 of the housing 82 is in free communication with atmosphere, as by ports 94. Suitable air filters, such as shown at 95 in Fig. 1, may be associated with the ports 94. It will thus be seen that the chamber 96 located on one side of large piston 84 is always at atmospheric pressure, while chamber 98, located on the opposite side of piston 84, may either be at atmospheric pressure or it may be vacuum charged, as will hereinafter be described in more detail. When the chambers 96 and 98 are both at atmospheric pressure, spring 100 resiliently urges piston 84 to the position illustrated in Fig. 2, it being seen that the piston 84 has moved to the right as far as it can go. In this position, the piston 68 has also been axially moved to the position illustrated, in which position extension 70 (Fig. 3) has engaged ball 64 to unseat it from valve seat 66. Thus, where chambers 96 and 98 are both at atmospheric pressure, the vehicle brakes are under the complete control of the brake pedal 12. However, when chamber 98 is vacuum charged, the pressure differential between chambers 96 and 98 is sufficient to overcome spring

100, whereupon piston 84 will move to the left, viewing Fig. 2, thus causing corresponding movement to the left of piston 68. This in turn enables ball 64 to seat against valve seat 66, by means of spring 62, thus blocking the bore 56 and preventing actuation of the brakes by means of brake pedal 12. As pistons 84 and 68 move further to the left due to the presence of a vacuum or even a partial vacuum in chamber 98, hydraulic pressure in lines 78 and 80 and in the spring-loaded brake actuators associated with the vehicle wheels will be relieved, due to the fact that the fluid is now free to back up into that portion of bore 56 that has been vacated by movement of piston 68 to the left. It will therefore be seen that by introducing a vacuum or partial vacuum to chamber 98, fluid pressure in lines 78 and 80 will automatically be relieved, thereby relieving the brakes. By the same token, as soon as atmosphere is again introduced to chamber 98 to equalize the pressure in chamber 96, the brakes can once again be fully actuated by the pdeal 12. It will be apparent that the amount of vacuum introduced to chamber 98 will determine the amount of reduction in brake pressure. More specifically, the greater the vacuum that is introduced to chamber 98, the greater will be the movement of piston 84 to the left (viewing Fig. 2) and at the same time there will be greater movement of piston 68 to the left, thus vacating more of bore 56 and providing greater relief of the hydraulic brake pressure. Similarly, given a certain amount of relief due to a certain amount of vacuum, then decrease in the amount of vacuum will increase the hydraulic brake pressure due to movement of the

pistons to the right. The ability of my system to provide varying degrees of relief and restoration of brake pressure while the brake pedal remains isolated from the system is an important and advantageous feature.

It will be noted that during normal operation of the system, as heretofore described, i.e., where atmospheric pressure exists in both chambers 96 and 98, the piston 68 will function as a pressure limitor in the sytem. More specifically, since the piston 68 is resiliently held in the position illustrated in Fig. 2 by means of spring 100, it will back off when excess pressure is applied by foot pedal 12. In practice it has been found that in a conventional automobile pressure above 1,000 p.s.i. or at least above 1,500 p.s.i., depending on the type of vehicle, is unneeded for normal brake operation and hence springs 62 and 100 are preferably calibrated so as to enable ball 64 to seat when pressure in excess of that needed is introduced, thus preventing introduction of excessive pressure to the brakes. It will be obvious that the springs may be calibrated so as to provide a limit at any selected pressure.

The means for introducing either atmospheric pressure or vacuum to chamber 98 and for modulating the degree of vacuum therein will now be described. Referring to Fig. 2, it will be seen that cylinder housing 82 is provided with an opening 102 in communication with chamber 98, which opening communicates with a brake control conduit 104 that in turn connects with the conduit valve, generally designated at 22. More specifically, there is provided a housing 106 having an upper portion 108

which houses the skid-sensing and control means 24, and a lower portion 110 which houses the valve 22. The lower housing 110 comprises an inner chamber 112 having a partition 114 defining a vacuum passage 116 and an atmosphere passage 118. More specifically, vacuum passage 116 is in communication, by means of passage 119, with the intake manifold 120 of the vehicle. Thus, suction is constantly being applied to the passage 116. The passage 118, on the other hand, is in communication with atmosphere through port 122, to which a suitable air filter 124 may be attached, if desired. A rotary valve 126 is mounted for rotation in housing 106, it being noted that valve 126 is an elongated rod that extends vertically through upper partition 128, the aforesaid partition 114, and is journaled in bottom wall 130, the partition and wall being integral parts of a unique molded housing of anti-friction plastic. The valve 126 is provided with a pair of passageways or bores 132 and 134 extending diametrically therethrough, said bores being vertically spaced from each other, and having elongated cross-sections in the axial direction, longer than the diameter of the rod. Bore 132 is associated with passage 116 and bore 134 with passage 118. The bores are angularly disposed with respect to each other, as shown most clearly in Fig. 6. Thus, with the rotary valve 126 in the position illustrated in Figs. 2 and 6, bore 134 is positioned so as to allow free passage of atmosphere from passages 122 and 118, bore 134 and chamber 112 to brake control conduit 104, whereby atmosphere will flow into chamber 98. At the same time, due to the angular displacement of bore 132, passage 116 will be closed by valve 126,

thus preventing suction from manifold 120 and passage 119 from coming into contact with chamber 112 and brake control conduit 104. It will be understood that the only access from passage 116 and 118 to chamber 112 is through valve 126 and more specifically, the bores 132, 134 thereof. Should valve 126 be rotated by means hereinafter to be described, it will be seen that communication between passage 118 and chamber 112 will eventually be blocked, thus interrupting the flow of atmosphere to brake control conduit 104, while at the same time passage 116 will be in communication with chamber 112, whereupon a suction will be applied through brake control conduit 104 to chamber 98.

It is important to note that use of a rotary valve such as valve 126 is extremely advantageous where passage of a vacuum and atmospheric pressure, or more generally two different pressures, is being controlled due to the fact that the pressure differential offers a minimum of resistance to the turning movement of the small diameter valve. This is contrasted to a reciprocal or poppet type valve wherein movement of the valve is much more resisted by pressure differential.

As hereinbefore explained and described, introduction of a vacuum or partial vacuum to chamber 98 automatically tends to release brake pressure on the vehicle wheels. It has been found in practice that an angular displacement between bores 132 and 134 of approximately 37.5° gives best results in the operation of my system, and it will be understood that rotary valve 126 may not always be positioned so as to completely open or close the bores 132 and 134. Thus, different degrees of movement of valve

126 allow different brake fluid pressures to be exerted on the vehicle wheels, thus providing the proper braking pressures for different road conditions. In instances where the pressure on the brake actuator is the same at the beginning of a skid, (lesser initial pressure requires less relieving), the amount of relief of the brake pressure depends on the amount of travel of piston 84 to the left in chamber 98 which in turn is dependent on the amount of vacuum introduced to the chamber. Thus, where the vehicle is braked and skids on a dry surface which requires a greater brake pressure to create a skid condition, lesser movement of piston 84 to the left, and hence less vacuum, will be required to relieve the brake pressure sufficiently to prevent the vehicle wheels from locking, this pressure being referred to as "release" pressure. Conversely, where the vehicle is braked on a slippery surface such as ice, a lesser brake pressure is required to create a skid condition. Hence the valve 126 must open suction passage 116 to the brake control conduit 104 for a longer initial period to provide greater vacuum to chamber 98 in order to move piston 84 sufficiently to the left so that sufficient relief of the brake pressure will be effected to prevent the wheels from locking.

In accordance with the invention after release pressure is attained, with corresponding movement of the piston then the governor causes the degree of vacuum in conduit 104 to modulate, which modulates the brake pressure through a narrow range of intermediate pressures above and below the release pressure, without ever restoring the normal, higher brake pressure until the skid condition ends.

To thus operate the valve, the upper extremity of valve 126 (Fig. 2) is provided with a reduced portion 136 that extends upwardly through partition 128, said portion 136 having a pin 138 extending therethrough to which is attached a circular projection 140, it being seen that as a longitudinal thrust is exerted against projection 140, the valve 126 will be caused to rotate.

The means for controlling movement of valve 126, namely, the skid-sensing and governor control means and the drive means therefor, will now be described. Referring to Fig. 4, skid-sensing and governor control means is designated generally at 24, and the drive means therefor is designated generally at 26. Referring first to the latter, the vehicle drive shaft is shown at 142, it being understood that the drive shaft is directly connected to the wheels of the vehicle (not shown) whereupon when the vehicle wheels lock, the drive shaft also locks. The drive shaft drivingly engages speedometer gear 144, which in turn is fixed to shaft 146, which in turn is drivingly connected to shaft 148 by means of a coupling shown at 150, said shaft 148 connecting with speedometer cable 152. Gear box 154 through which shaft 148 passes and in which the shaft 148 is suitably journaled, houses drivingly engaged bevel gears 156, 158, it being understood that bevel gear 156 is keyed to shaft 148 and bevel gear 158 is keyed to shaft 160, whereupon rotation of shaft 148, transmitted thereto by the vehicle drive shaft 142, is transmitted to shaft 160. Shaft 160, in turn, is drivingly interconnected, as at 162, to flexible shaft 164, said flexible shaft being connected, as at 166, to the unit 24, and said flexible shaft being drivingly

interconnected with a shaft 168 which has fixed thereto a drive gear 170. It will therefore be seen that the gear 170 is drivingly interconnected with the vehicle drive shaft 142, which in turn is connected to the vehicle wheels. Thus, rotation of the vehicle wheels will cause corresponding rotation of gear 170, and, conversely, sudden slowing of the vehicle wheels, such as would occur where the vehicle approaches a skid condition by the operator applying more brake pressure than is required for a particular road surface, will cause not only the main drive shaft 142 to suddenly slow, but also drive gear 170. Gear box 154, and adaptor 172, by means of which the gear box is connected to the engine housing 174, comprise an assembly which may be easily and readily adapted to a conventional vehicle for driving the sensing and governor control means now to be described.

The unit 24 (Figs. 1, 4) comprises a molded plastic housing 176 having a pair of spaced partitions 178, 180 therein defining chambers 182, 184 and 186. A solenoid 188 is secured to housing 176 adjacent chamber 182 by any suitable means, the solenoid 188 having a plunger 190 with a reduced extension 192 resiliently urged into chamber 182 by means of spring 194. When solenoid 188 is not energized, spring 194 bears against flange 196 affixed to plunger 190 to resiliently urge extension 192 into chamber 182. Suitable stop means 198 mounted on the interior of chamber 182 engaged flange 196 to limit resilient axial movement of plunger 190 and extension 192 at a predetermined point, for reasons hereinafter to be explained more fully. Journaled in the partitions 178 and 180 are a pair of aligned shafts 200 and 202,

respectively. Shaft 202 is provided with an enlarged portion 204 having an internal bore for slidably receiving in telescoping relation a reduced extension 206 of shaft 200. Attached to shafts 200 and 202 is a governor assembly comprising a plurality of weights 208, each pivotally connected to a pair of links 210, which links in turn are pivotally connected to arms 212. The arms 212 located on one side of the weights 208 are affixed to shaft 200 as at 214, while the arms on the other side of the weights are affixed to shaft 202 as at 216. As hereinbefore pointed out, shaft 202 is journaled for rotation in partition 180 but is incapable of longitudinal movement. Shaft 200, on the other hand, is drivingly engaged with shaft 202 so as to rotate therewith, but said shaft 200 is axially slidable with respect to the said shaft 202. Since the governor assembly is affixed on one side to shaft 202 and on the other side to shaft 200, it will be seen that the speed of rotation of the shafts will determine their longitudinal position relative to each other. Spring 218 resiliently urges the governor assembly to its collapsed position wherein shafts 200 and 202 are axially extended with respect to each other, but as the rotational speed of shafts 200 and 202 increases, centrifugal force urges the weights 208 outwardly, thus moving shaft 200 toward the right, viewing Fig. 4, against the action of spring 218.

Fixed to shaft 200 at the extremity thereof located in chamber 182 is a spool member 220, which spool member is in engagement with projection 140 carried by the reduced upper extension 136 of rotary valve 126. Thus, axial movement of shaft 200 causes like movement of the spool 220 which in turn carries therewith projection 140 captured between the opposed walls

of the spool to thereby impart rotary movement to valve 126.

The means for imparting rotational movement to shafts 200 and 202 and the governor assembly associated therewith comprises a cam gear 222 (Figs. 4, 5 and 5A), which cam gear is part of the drive train, in driven engagement with gear 170. The cam gear 222 is mounted on shaft 202 and is located in chamber 186. The cam gear is slidably mounted on shaft 202 and is in driving engagement therewith by means now to be described. A recess 224 having inclined or helical surface 226 is provided at the end of the cam gear adjacent partition 180, and a projection or pin 228, carried by shaft 202, extends into said recess in engagement with the cam surface 226. At either end of the recess is a stop surface, at the deeper end stop surface 227, adapted to engage pin 228 for accelerating the governor and at the shallower end stop surface 225 for engaging pin 220 to decelerate the governor. A leaf spring 230 mounted to the housing 176 by any suitable means engages a button 232 which is press fitted into the central bore of cam gear 222 to normally urge the latter axially toward partition 180, holding pin 228 against accelerating stop surface 227. However, when rotation of drive gear 170 and cam gear 222 is suddenly slowed, as by sudden slowing of the vehicle wheels upon the presence of a skid condition, the rotational inertia of shaft 202, especially due to the governor weights 208, causes shaft 202 to turn ahead of gear 222, causing pin 228 to leave stop surface 227 and move to stop surface 225. This slides gear 222 on shaft 202 in a direction away from partition 180 to activate governor control.

It is important to note that solenoid spring 194 is stronger than governor spring 218, whereupon when solenoid 188 is not energized, plunger extension 192 bears against spool 220 to restrain same in the position illustrated in Fig. 4 wherein the rotary valve 126 is in the position illustrated in Fig. 6, namely, the position where atmosphere is free to pass through the valve to conduit [illegible] and then to chamber 98 and wherein at the same time suction from the intake manifold is blocked from communication with conduit 104. This is the normal operating condition of the system wherein the balanced pressure on opposite sides of actuator piston 84 enables spring 100 to position piston 84 and piston 68 as illustrated in Fig. 2. In this position, ball valve 64 is unseated to allow fluid pressure to pass directly to the brake line whereupon operation of the brakes is under direct control of brake pedal 12. This condition will remain so long as solenoid 188 (Fig. 4) is not energized. Energization of solenoid 188 is accomplished in the following manner. As previously explained, sudden slowing of gear 170 due to sudden slowing of the vehicle wheels as a result of a skid condition causes cam gear 222 (Figs. 4, 5, 5A) to move axially on shaft 202 away from partition 180 against the action of spring 230. This movement is sufficient to cause actuation of a switch 234 suitably mounted in chamber 186. At the same time, the initial movement of the brake pedal and the resultant increase in fluid pressure in the system, causes hydraulic switch 18 (Fig. 2) to become closed. Hydraulic switch 18 is fully disclosed and described in copending U. S. patent application Serial No. 203,075,

filed June 18, 1962. Basically, switch 18 comprises piston 236 which has connected thereto at its upper end a metallic contact cup 238. Cup 238 is adapted to bridge contacts 240 and 242 but is normally maintained spaced therefrom by spring 244. An adjusting screw 246 is provided by means of which the tension of spring 244 may be varied, thus enabling the switch 18 to be pre-adjusted whereby a predetermined fluid pressure, e.g., 120-125 p.s.i., will cause piston 236 to move against the action of spring 244 sufficiently to bridge the contacts 240, 242. Actuation of switch 18 in the aforedescribed manner enables current to flow from battery 248 through contact 242, contact cup 238, and contact 240 to line 250 to the solenoid coil positive terminal 252 (Fig. 4). The voltage is applied through the solenoid coil 254 and then through line 256 to terminal 258 on switch 234. When switch 234 is open, the circuit to ground is not complete, and solenoid 188 will not be energized. However, upon actuation of switch 234 in the manner aforedescribed, the circuit to ground is completed through terminal 260, line 262 and ground connection 264. It is important to note that the circuit is such that although it is essential for hydraulic pressure switch 18 to be closed in order for solenoid 188 to be energized, closing of switch 18 alone is not sufficient, but rather switch 234 must also be actuated in order to complete the circuit. This is important because under normal operating conditions of the system sufficient pressure will normally be introduced to switch 18 by the foot pedal to actuate same, but it is essential that solenoid 188 not be energized under such normal conditions.

Energization of solenoid 188 accomplished by rightward movement of the cam gear (Fig. 5) closing switch 234, causes plunger 190, 192 to be retracted against the action of spring 194, thus freeing the shaft 200 and spool 220 for axial movement under the influence of the governor assembly. Therefore, the cam gear operating in response to the inertia of the governor and the solenoid operated plunger together can be regarded as an inertia-responsive means for initiating the action of the governor.

As soon as the solenoid plunger has been retracted, due to the sudden slowing at the commencement of a skid condition, the governor assembly takes over control and, as it is stopped by ~~stop surface~~ stop surface 225 of the cam gear, spring 218 will cause the governor assembly to commence to collapse, thus moving shaft 200 and spool 220 axially to the left, when viewing Fig. 4. This movement of spool 220 causes corresponding rotary movement of valve 126, thus shutting off the passage of atmosphere to brake control conduit 104 and simultaneously effecting communication between vacuum passage 119 and conduit 104. This results in suction being introduced to chamber 98 which in turn overcomes the action of spring 100 to cause pistons 84 and 68 to move to the left, viewing Fig. 2. This movement of piston 68 enables ball valve 64 to close due to the action of spring 62, thus preventing the introduction of further fluid pressure to the system via brake pedal 12. Further leftward movement of piston 68 enables the fluid in lines 78 and 80 to back up, thereby relieving the pressure until the vehicle brakes begin turning, the duration that the suction is applied, and hence the degree

of vacuum and the amount of pressure relief depending on the slipperiness of the road. As soon as the brake release pressure is achieved, the vehicle wheels commence to rotate, whereby drive shaft 142 through the aforedescribed gearing once again causes gears 170 and 222 to rotate, it being apparent that this renewed rotation of shafts 200 and 202 will cause the governor assembly to once again turn, and due to the centrifugal force created, to retract shaft 200 and spool 220 to once again rotate valve 126 to the positions illustrated in Figs. 2 and 4, where once again atmosphere is connected to chamber 98, thus enabling brake pressure to be restored.

But, it is very important for my present invention that the solenoid is not de-energized and the governor returned to the restraint of the inertia-responsive device. Rather, the governor remains free to act. It leaves the valve 126 open to atmosphere 118 for an instant until the degree of vacuum is lessened enough to cause slight rightward movement of the piston 84 to cause the brake pressure to slightly exceed release pressure and a skid again commences. Again the governor is slowed by the drive train and again it opens the valve 126 to suction 116, and this cycle repeats again and again in an extremely rapid hunting or modulating action with the gas pressure in the conduit 104 never reaching either atmospheric or engine vacuum level, but rather modulates at intermediate levels. In dependent fashion, the hydraulic brake pressure modulates narrowly about the release pressure as a mean, without returning to normal pressure. When the skid condition ends, the governor opens the valve continually to atmosphere and pistons 84 and 86 move full, to the right to once again unseat insolation valve 64 and restore normal brake operation. The faster the vehicle travels, the faster does this action occur, but the action is sufficiently fast down to speeds on the order of 10 m.p.h. and

even lower, to rapidly pump and release the brakes. It is another very important aspect of the invention that the governor relinguishes control of the brake pressure before the vehicle stops.

In order to effectively carry out this modulating action, I have found it to be critical, in the preferred construction, that the solenoid 188 remain energized or that the plunger in some other way remains retracted until the vehicle slows to a predetermined slow speed, e.g., 5 or 10 m.p.h., depending on the vehicle. Since closing of switch 234 to complete the circuit to ground that energizes solenoid 188 is only momentary, holding means are provided for maintaining the solenoid energized until hydraulic pressure switch 18 opens, it being understood that switch 18 is preset to open only when fluid pressure in the system falls below the minimum value possible to achieve a skid condition, e.g., set to 85-90 p.s.i. produced by the governor at 5 or 10 m.p.h.

The aforesaid holding means for the solenoid comprise a terminal 266 having a connection to ground as at 268, which terminal is engaged by plunger 190 when the latter is retracted in order to complete the circuit to ground independent of switch 234. Thus, although closing of switches 18 and 234 is essential in order to energize solenoid 188, once the solenoid has been energized and its plunger retracted, switch 234 may be opened without de-energizing the solenoid, and the solenoid will remain energized until switch 18 opens.

As hereinbefore stated, it will be obvious that if switch 18 were not utilized, then there would be no means present for insuring de-energization of the solenoid once the condition has been reached where a skid is no longer possible, it being obvious that if the solenoid were still energized at such low speeds, the vehicle would be without effective brakes, since the governor assembly would not exert sufficient centrifugal force to overcome the action of spring 218 and move shaft 200 and spool 220 to the rightward position (Fig. 4) wherein valve 126 enables the brakes to be controlled by pedal 12.

It is possible for the reset device to take some other form, such as a pendulum device or a vehicle inertia memory system that can detect the slow speed of the vehicle, but brake pressure-sensitive devices, and particularly hydraulic-electric switches have important advantages in the system, particularly since they can respond whenever the skid condition has passed, regardless of the speed of the car, to enable normal operation, while offering low speed protection against the governor's cutting off the brakes completely. The adjustment of the pressure level to which the device responds can be adjusted according to the wishes of the operator and the type of road conditions to be expected. But, in fact, a single setting, below that at which skidding on ice occurs, which is determinable for any given vehicle, is advantageously employed to give anti-skid protection under virtually all conditions.

Any tendency for the unit 24 to erroneously sense a skid condition and actuate switch 234 in response to a rapid deceleration is overcome by use of properly calibrated weights 208 and a properly tensioned spring 230. In addition, I have found that an erroneous sensing is most likely to occur where there is a rapid acceleration of the drive shaft quickly followed by a rapid deceleration. The frictional brake or drag that is resiliently exerted on spool 220 by plunger 190 helps to overcome this problem since this action tends to reduce the torque applied to shafts 200 and 202 by the governor assembly. It has been found, however, that at high speeds the frictional engagement between plunger 190 and spool 220 results in undue wear of the parts. Therefore, plunger 190 is assisted by spring 230, and the plunger is disengaged at high speeds. To this end, stop means 198 engages flange 196 so as to limit the outward movement of plunger 190 whereupon no engagement exists between plunger 190 and spool 220 at relatively high speeds. I have realized that the crucial problem of rapid acceleration followed by rapid deceleration occurs at low speeds in the low gear range with conventional automobiles, and I have, therefore, found that it is not necessary to have plunger 190 exert a frictional drag on spool 220 and shaft 200 at relatively high speeds.

Although the operation of my invention is thought to be clear from the foregoing description, a brief resume of the operation will now be given. Under normal operating conditions, solenoid 188 is de-energized whereby the spring-loaded solenoid plunger maintains the skid-sensing and control unit inoperative.

The de-energized solenoid further insures that rotary valve 126 is in the position wherein atmosphere is introduced to chamber 98. Since chamber 96 is also open to atmosphere, it follows that there is a pressure balance on each side of large piston 84 thus enabling spring 100 to take over and move the piston 84 to the position illustrated in Fig. 2. In this position, piston 68, which is connected to piston 84 and moves therewith, engages ball valve 64 so as to unseat same against the action of spring 62. With ball valve 64 so opened, fluid pumped from master cylinder 14 by brake pedal 12 is free to pass directly to hydraulic lines 78 and 80 to actuate the vehicle brakes. The pressure-sensitive switch is adapted to be closed by a low level of brake pressure, e.g., 120-125 p.s.i., placing the anti-skid unit into readiness for operation.

Upon encountering a skid condition, i.e., a condition wherein the vehicle operator applies more brake pressure than is required for a particular road surface, the vehicle wheels slow suddenly. This causes corresponding deceleration of drive shaft 142, and, through suitable gearing, drive gear 170 and cam gear 222 also slow abruptly. The inertia of the governor assembly causes the gear 222 to move longitudinally by the cam surface aforedescribed, said longitudinal movement of gear 222 causing switch 234 to be closed which results in energization of solenoid 188 and the retraction of solenoid plunger 190. The second switch or terminal 266 is engaged upon retraction of the solenoid plunger to maintain the solenoid energized until switch 18 opens, even though switch 234 has now opened. Switch 18 is preset, e.g., at

85-90 p.s.i. to be opened at a brake pressure below that at which skids can occur, e.g., 100-150 p.s.i. for ice, whereupon solenoid 188 will remain energized until possibility of skidding no longer exists, and the solenoid is then de-energized to restore normal foot brake action before the governor has a chance ever to totally relieve the brakes.

Regarding the operation of the governor, once the solenoid 188 has been energized, the governor control unit takes over. More specifically, when a skid condition is approached, the sudden slowing of the vehicle wheels causes the governor assembly to collapse under the action of spring 218, thus moving shaft 200 and spool 220 to rotate valve 126, this movement now being permitted due to retraction of plunger 190. Rotation of valve 126 blocks the flow of atmosphere to chamber 98 and simultaneously allows the introduction of a vacuum to said chamber. The introduction of vacuum overcomes spring 100, thus resulting in movement of pistons 84 and 68 to the left, viewing Fig. 2. This movement closes isolation valve 64, thus preventing the application of further fluid pressure by brake pedal 12. As the valve remains in this position, the degree of vacuum increases, causing further leftward movement of piston 68 (Fig. 3), so that pressure in lines 78 and 80 and the brakes are relieved. A point is reached when the brakes are relieved sufficiently to allow the wheels to speed up from their slowed condition, the degree of relief required depending on the degree of slipperiness of the road. Then shafts 200 and 202 speed up once again, whereby the governor assembly retracts shaft 200 and spool 220 to once again rotate valve 126 to the position where

atmosphere is introduced to chamber 98 and the piston 68 moves to the right and increases the brake pressure, until a part is reached where the wheels slow again and the cycle repeats. This action continues in a hunting manner so long as the vehicle is in an incipient skid, thus insuring that maximum brake pressure is continually applied to the wheel brakes short of pressure that would cause locking of the wheels. Once the brake pedal is released or the brake pressure in the system has dropped below the minimum possible value to create a skid, hydraulic pressure switch 18 breaks the circuit to solenoid 128, whereupon the latter becomes de-energized and the brakes once again become under complete control of the operator.

It is important to note that although loss of vacuum in the vehicle system will render the anti-skid means ineffective, said loss of vacuum will in no way affect normal operation of the vehicle brakes. Also, it is important to note that this system can be used with foot pedal controlled brakes of both the powered and nonpowered types.

While a spring-loaded fly ball type of governor has been illustrated, and is presently preferred, the broad concept of the invention include the use of other governors, all rotary weight governors, such as gravity loaded fly ball, centrifugal shaft and inertial shaft governors, as well as governors that operate through electrical action.

The concepts are likewise applicable to other brake systems including air brakes in which valve 126 could directly modulate air brake pressure. Likewise it is possible to separate the governor from the valve, let the governor actuate a switch and let the valve be actuated by a solenoid responsive to the condition of the switch.

While use with engine vacuum is very efficient and inexpensive, and unlike previous systems I have proposed, does not cause the engine to run roughly due to loss of vacuum, the invention is applicable to other sources of pressure differential, incompressible fluid as well as gaseous fluid and numerous aspects of the invention are useful with nonfluid types of brake systems.

Referring now to Figs. 7 and 8, a slightly different form of my invention is disclosed in which the relieving device is incorporated as an integral part of a power brake unit. The system generally comprises a brake pedal 300, a master cylinder 302, an accumulator 304, a safety valve 306, a hydraulic pressure switch 308, a power brake control unit 310, and an anti-skid unit 312.

Actuation of brake pedal 300 operates piston 314 to pump fluid from cylinder 316 to conduit 318. Master cylinder 302 further comprises a fluid reservoir 320 communicating with cylinder 316 by means of passageway 322. A conduit 324 extends from reservoir 320, the function of which will hereinafter be described. Accumulator 304 is in communication with conduit 318 and comprises a spring loaded piston 326 and acts as a cushion and shock absorber for the fluid system where variations in fluid pressure occur.

During normal operation of the vehicle with which the power brake unit is associated, and with the brakes in their non-actuated position, the power brake unit 310 is in the position illustrated in Fig. 8. In this position, chambers 328 and 330 of cylinder 332 are both under vacuum, thereby equalizing the pressure on opposite sides of piston 334. This enables spring 336 to urge the piston 334 to the leftward position illustrated, said piston 334 being connected by means of rod 338 to a brake actuating piston 340. Piston 340 is slidably mounted in cylinder 342, said cylinder having an outlet conduit 344 leading to safety valve 306. Conduit 344 is also in communication with hydraulic pressure switch 308.

A supply of hydraulic fluid is located in cylinder 342 whereupon movement of piston 334 against the action of spring 336, and corresponding movement of piston 340 will force fluid from cylinder 342 under pressure through conduit 344 and with valve 306 in the position illustrated in Fig. 8 to conduit 346 and then to hydraulic lines 348 which lead to the wheel cylinders (not shown) of the vehicle's braking system. Thus it will be seen that movement of pistons 334 and 340 to the right, viewing Fig. 8, will cause operation of the vehicle brakes.

As hereinbefore indicated, under normal operating conditions of the vehicle, and with the brakes not applied, pistons 334 and 340 are in the position illustrated in Fig. 8 due to the fact that a vacuum exists in both chambers 328 and 330. More specifically, suction from the intake manifold 350 of the vehicle passes through conduit 352 into chamber 330 and then through passageway 354, through openings 356 in diaphragm 358 to conduit 360, through rotary valve 362 of the anti-skid unit 312, through conduit 364 and then to chamber 328. The control unit generally shown at 366 which forms a part of power brake unit 310 is of conventional form and comprises the aforesaid diaphragm 358, hydraulically movable by means of piston 368 to a closed position wherein the diaphragm engages the fixed seat 370 to block communication between passage 354 and conduit 360. The piston 368 also controls movement of poppet valve 372 normally maintained closed by spring 374. Spring 376 normally urges diaphragm 358 to its open or unseated position, as illustrated in Fig. 8. An atmosphere intake is located at 378, and introduction of atmosphere into the system is controlled by valve 372 in a manner now to be described.

As above indicated, with the parts in the positions illustrated in Fig. 8, the brakes of the vehicle are non-operative due to the fact that suction is free to circulate through conduit 352 to chamber 330 and then through control unit 366 to conduit 360, through rotary valve 362 to conduit 364 and then to chamber 328. With vacuum on both sides of piston 334,

spring 336 maintains the piston 334 and the connected brake actuating piston 340 in brake release position. Upon actuation of brake pedal 300 by the operator, pressurized fluid passes through conduit 318 to conduit 380. With the safety valve 306 in the position illustrated, flow of the fluid into the valve is blocked, and hence the brake fluid is forced to flow through conduit 380 into the brake control unit 366. None of the fluid from the pedal is allowed to reach the brake actuators at 348.

C43 Introduction of the pressurized fluid to the brake control unit 366 causes actuation of piston 368 to move diaphragm 358 to its closed or seated position and to simultaneously open poppet valve 372 in a conventional manner. This movement blocks communication between chamber 330 and conduit 360 and simultaneously allows air to enter through inlet 378 through the now open valve 372 to conduit 360. The atmosphere circulates around conduit 360 through valve 362 to conduit 364 and then the chamber 328. The introduction of atmospheric pressure to chamber 328 creates a pressure differential which overcomes spring 336 and moves piston 334 and piston 340 to brake actuating position. More specifically, the movement of piston 340 in cylinder 342 forces the brake fluid through conduit 344 and safety valve 306 to conduit 346 and hydraulic brake lines 348 to actuate the vehicle brakes in known fashion.

In order to insure that there is always an adequate supply of brake fluid in cylinder 342, conduit 324 connects fluid reservoir 320 to the cylinder 342, it being important to note that the inlet 382 to the cylinder 342 is located behind the forward portion of piston 340. Piston 340 is provided with a one-way valve 384 which enables fluid to pass through the piston from left to right, viewing Fig. 8, but which blocks flow of fluid through the piston from right to left. Thus, during operation of the piston 340, the suction created thereby in cylinder 342 sucks fluid through conduit 324 from reservoir 320 into cylinder 342 on the rear side of piston 340. During the return stroke of piston 340, the valve 384 allows fluid to pass Ex43 through the piston, thereby insuring that there is always a full supply of fluid in the cylinder for brake actuation.

Since the structure and operation of hydraulic pressure switch 308 and anti-skid unit 312 are identical to that already described in connection with the first form of my invention, it is not thought that further description is necessary. It will be noted, however, that where the operator applies more brake pressure than is required for a particular road surface, the vehicle wheels will lock, whereby the same structure and operational sequence will cause rotary valve 362 to be moved to a position wherein conduit 360 becomes blocked and conduit 352A becomes open to allow suction from manifold 350 to be introduced through conduit 364 to chamber 328, whereupon spring 336 will once again take over to release the brakes. The same modulating action as aforedescribed will take place until hydraulic pressure switch 308 eventually renders the anti-skid inoperative.

In accordance with my invention it is crucial that the entire brake pressure be controlled by the anti-skid unit and that no fluid be conducted directly from the foot pedal to the wheels. Means are provided to insure that brake pressure will not be lost should there be a loss of suction. This is accomplished by safety valve 306. More specifically, conduit 352B is connected to the suction conduit 352 whereupon as long as proper suction exists in the system, piston 386 is maintained in the position illustrated in Fig. 8 against the action of spring 388. In this position, conduit 344 is in communication with conduit 346, but conduit 380 is blocked at its extremity adjacent the safety valve. Should suction be lost in the system, spring 388 will become effective to move piston 386 upwardly, thereby blocking the communication between conduits 344 and 346 and at the same time providing communication between conduit 380 and conduit 346. With the safety valve in this position, the brakes are directly controlled by operation of pedal 300 since the entire power unit is now bypassed.

A one-way check valve 390 is located in conduit 352 adjacent the intake manifold 350 since without same backfire of the vehicle engine would cause an explosive pressure to be introduced to the power unit, which would be undesirable for obvious reasons.

Referring once again to Fig. 4, it will be noted that should the vehicle move in reverse, the direction of rotation of drive shaft 142 will likewise be in reverse, thus causing reverse rotation of flexible shaft 164 and shaft 168. Reverse rotation of shaft 168 will, in turn, cause reverse rotation of drive gear 170 and cam gear 222, causing pin 228 to leave stop surface 227 and move toward stop surface 225, which, as previously described, causes gear 222 to slide on shaft 202 in a direction away from partition 180 to close switch 234 and thus activate the governor control and anti-skid means. Even though it is possible that very slow reverse movement of the vehicle might not be sufficient to cause movement of cam gear 222 to activate the governor control, the fact remains that there is always the possibility and even likelihood that reverse movement of the vehicle will activate the governor control even though no skid condition exists. Since there is no practical need for any anti-skid means when the vehicle is moving in reverse, and since the activation of these means when not needed might even result in the loss of some stopping distance, it has been found desirable to provide means for rendering the governor control and anti-skid ineffective and inoperative when the vehicle moves in reverse.

Referring to Figs. 9 through 12, a somewhat modified anti-skid unit is shown generally at 400. Unit 400 is basically the same as skid-sensing and control means 24 hereinbefore described except that a reverse cut-off switch

has been incorporated in the unit to prevent energization of solenoid 188 when the vehicle drive shaft is in reverse and flexible shaft 164 correspondingly rotates in a reverse direction. The reverse cut-off switch, shown generally at 402 (Fig. 10) comprises a shaft 404 slidably coupled to shaft 164 as at 406, in the same manner that shaft 168 was drivingly engaged to flexible shaft 164. Shaft 404, which is constructed of any electrically conductive metal, is journalled in bore 408, said bore having an enlarged end portion 410, it being understood that the larger diameter of portion 410 results in the presence of an annular shoulder 412 at the extremity of bore 404. Slidably mounted in portion 410 is a contact button 414, said button being resiliently urged toward bore 404 by means of spring 416. The opposite end of spring 416 resiliently engages a contact cup 418 having a terminal 420 extending radially therefrom.

Adjacent its opposite extremity, shaft 404 has fixedly mounted thereon the afore-described drive gear 170, said gear meshing with cam gear 222, all in the manner hereinbefore described. A spring 422 engages washer 424 to normally urge shaft 404 to the left when viewing Figs. 9 and 10, thus causing the end of shaft 404 to extend into enlarged portion 410 and, therefore, into engagement with contact button 414, as illustrated in Fig. 9. Loosely mounted on shaft 404 is a reverse switch cam 426 comprising a circular plate 428 having a spiral cam portion 430 mounted thereon, and further having an outwardly extending

pin 432 located adjacent the end of cam track 430. A cam pin 434 extends radially from shaft 404 and is adapted to cooperate with the spiral cam track 430 to determine the axial position of shaft 404. Expressed differently, when shaft 404 is rotating in a counterclockwise direction when viewing Fig. 12, cam pin 434 will engage the stop pin 432 at the low point on the spiral track 430. With the parts in this position, shaft 404 will assume the position illustrated in Fig. 9 wherein the extremity of the shaft is in engagement with contact button 412, it being understood that spring 422 is somewhat stronger than spring 416, whereupon the extremity of shaft 404 will actually enter into enlarged portion 410. Upon clockwise rotation of shaft 404, pin 434 will ride up the spiral cam track 430 until it reaches the high end of said track and engages the opposite side of stop pin 432, as illustrated in Fig. 10. In this position, shaft 404 has been moved to the right (when viewing Fig. 10) against the action of spring 422 sufficiently for the end of said shaft to become completely withdrawn from enlarged portion 410. Since the annular shoulder 412 prevents the contact button 414 from moving out of enlarged portion 410, it follows that the end of shaft 404 becomes disengaged from contact button 414, as clearly illustrated in Fig. 10. Also mounted on shaft 404 is a washer 436 having a radially extending contact arm 438, the purpose of which will hereinafter be described. As will be seen most clearly in Fig. 10, the washer 436 is mounted

on shaft 404 adjacent the flat rear surface of cam 426, it being understood that shaft 404 may freely rotate within washer 436. A cam thrust washer 440 comprising a peripheral ring portion 442 and bent marginal lugs 444 resiliently engages the opposite face 428 of cam 426, whereupon to resiliently urge cam 426 into engagement with washer 436 and at the same time to impart a sufficient frictional drag on cam 426 so that movement of shaft 404 will not impart corresponding rotary movement to the cam until pin 434 moves into engagement with stop pin 432. The thrust washer 440 has a radially extending spring arm 446 that is secured to the housing 176 by any suitable means, such as by having the end of the spring arm clamped between adjacent portions of the housing, as illustrated in Figs. 9 and 10.

The operation of reverse switch 402 is as follows. Assuming that shaft 404 is being rotated in a counter-clockwise direction, which for purposes of this description corresponds to forward movement of the vehicle, the switch will, as afore stated, assume the position illustrated in Fig. 9 wherein shaft 404 is making engagement with contact button 412. With the parts in this position, and assuming that a skid condition commences to exist, causing cam gear 222 to close switch 234, current will flow through line 262 to terminal 420 through contact cup 418, spring 416, contact button 414, and then to shaft 404, which as previously described, is in engagement with contact button 414. Shaft 404 is in turn in electrical engagement with washer

436 and its radially extending terminal 438, both directly and through the engagement of pin 434, which in turn engages cam 426, which in turn bears against washer 436. Thus, the flow of current is through terminal arm 438 and then to line 262A, which connects to ground as at 264. This, along with line 256, completes the circuit to solenoid 188 in order to energize same and render the governor control effective, all in a manner hereinbefore described. On the other hand, should the vehicle move into reverse, thus resulting in clockwise rotation of shaft 404, cam 426 will cause the shaft 404 to retract and become disengaged from contact button 414, as illustrated in Fig. 10, thus interrupting the connection to ground and preventing energization of solenoid 188. It will thus be seen that whenever the vehicle and its drive shaft moves in reverse, the reverse cut-off switch 402 will automatically prevent the skid sensing and control means and the governor control from coming into play. Thus, the vehicle brakes will always be under normal and direct control by the operator whenever the vehicle is moving in reverse.

While there is shown and described herein certain specific structure embodying the invention, it will be manifest to those skilled in the art that various modifications and rearrangements of the parts may be made without departing from the spirit and scope of the underlying inventive concept and that the same is not limited to the particular forms herein shown and described except insofar as indicated by the scope of the appended claims.

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I Claim:

1. A control system for operating a vehicle wheel brake-relieving device for the purpose of preventing skids, said control system comprising the combination of an inertia-responsive means adapted to respond to a sudden decrease in the speed of rotation of the wheel and thereupon to initiate the operation of said relieving device, a rotary governor means adapted to rotate dependently with the speed of the wheel and adapted after said operation is initiated by said inertia-responsive means to correspondingly vary the condition of said relieving device, to decrease and increase the brake pressure dependently with decrease and increase in the speed of the wheel, and a reset means adapted to respond to a predetermined, decreased speed of the vehicle, to terminate the operation of said relieving device, and reset said inertia-responsive means so that it may again initiate said operation.

2. The system of claim 1 wherein said reset means includes a pressure-responsive means, adapted to respond to a predetermined decreased brake pressure level, said governor means adapted to produce said level when said vehicle reaches said predetermined decreased speed, said predetermined brake pressure level being below the lowest level which the governor means can produce when said vehicle travels at speeds in excess of said predetermined speed.

3. The system of claim 2 wherein said inertia-responsive means that initiates the operation of said relieving device is adapted to operate with electrical power, a power source for said inertia-responsive means, said pressure-sensitive means being adapted to switch off said power source from said inertia-responsive means when said brake pressure is at or below said predetermined level, to prevent the operation of said relieving device, and said pressure-sensitive means adapted to switch on said power source to said inertia-responsive device when said brake pressure is above said predetermined level, so that said control system is placed into condition for operation whenever the brakes are operated.

4. The system of claim 2 wherein said reset means comprises a pressure-sensitive switch set to respond to a predetermined brake pressure below that brake pressure which can cause skidding of said wheel on ice.

5. The system of claim 1 wherein said inertia-responsive means includes a control member associated with said governor, said member normally urged to a first state to prevent said governor from operating said relieving device, a solenoid associated with said governor control member, adapted when energized to move said control member to an inactive state to free said governor to operate, a switch-actuating member adapted to be moved under the influence of the rotary inertia of said governor when said wheel changes speed suddenly, said switch-actuating member adapted to close and open a switch depending on whether said wheel is slowing down or speeding up, said switch adapted, when closed, to energize said solenoid, and wherein a holding means is provided to retain said solenoid energized when said switch thereafter opens, and said reset means is adapted to de-energize said solenoid, to allow said governor control member to return to said first state.

6. The system of claim 5 wherein said governor control member comprises a plunger disposed within the coil of said solenoid, and said holding means comprises a second switch associated with said solenoid, positioned to be engaged by said plunger when in the inactive position, said switch adapted to complete the circuit for said solenoid independent of said first switch, thereby serving to maintain said solenoid energized when said first switch opens.

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7. A skid control system for a pressure-operated vehicle wheel brake, the pressure at said brake normally controlled by the driver of the vehicle, said control system comprising an anti-skid means adapted, on the occurrence of a skid condition during braking, to repeatedly decrease the pressure at the vehicle wheel brake dependently with decrease in the speed of the wheel, and a pressure-sensitive switch set to detect the decrease of the pressure at the wheel brake to a predetermined minimum level, and thereupon remove the influence of said anti-skid means and return to normal control the pressure at said wheel brakes.

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8. A control apparatus adapted to control braking of a vehicle wheel during skid conditions comprising a rotary weight governor device adapted to rotate dependently with said wheel, said governor device having a member adapted to move between a first position and a second position dependently with changes in the speed of rotation of said governor device, a brake pressure control means responsive to said movement to relieve said brakes when said member is moved toward the first position with decrease in wheel speed and restore the pressure of said brakes when said member is moved toward the second position with increase in wheel speed, a restraining means operable between an active state at which it maintains said member of said governor in said second position at which the brake pressure is under the control of vehicle driver, and an inactive state at which it allows said governor member to move, and means adapted to place said restraining means in said inactive state when a wheel skid condition first occurs, the improvement wherein means are provided for maintaining said restraining means steadily in its inactive state, once said inactive state is reached, to allow said governor to move said member repeatedly between said positions, dependently upon the speeds of the wheel, whereby the brake pressure can be controlled at a level near but below the pressure at which locking of the wheel occurs, and reset means adapted to reactivate said restraining means when the vehicle slows, before it has stopped.

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9. The control apparatus of claim 8 including a rotary valve associated with said governor for controlling said brake pressure through a gas pressure conduit, said rotary valve having a rotary member adapted to vary the pressure in said conduit dependently with changes in its rotary position, a projection extending from said rotary member and mechanically connected to said movable member of said governor to cause said rotary member to move dependently with said governor member.

10. The control apparatus of claim 8 wherein said rotary weight governor is of the fly ball type having a rotatable shaft free to move axially in response to speed changes, and said restraining means comprises a movable plunger, in its active condition urged against said shaft in a manner to prevent outward movement of the latter, said inertia-responsive means adapted to respond to the rotary inertia of said governor when said wheel slows, and a stop member limiting the movement of said movable plunger so as to prevent engagement with said shaft at relatively high rotational speeds due to axial movement of said shaft inwardly to a position out of the range of said movable plunger whereby frictional drag is applied by said movable plunger to said shaft only at relatively low rotational speeds.

11. In a skid control system adapted to control brake pressure upon a vehicle wheel brake, the pressure at said brake normally controlled by the driver of the vehicle, said system comprising a valve and a skid control device adapted to control said valve, said valve connected to a brake control conduit the pressure in which determines the value of the brake pressure, said valve adapted alternatively, dependent upon the position of the valve, to cause said conduit to communicate with two passages, the pressure in said first passage adapted to be maintained at a first value, and the pressure in said second passage adapted to be maintained at a second, different value, said system adapted, when the pressure in said conduit reaches said first value, to enable normal application of the brake pressure by the operator, and when the pressure in said conduit reaches said second value, to substantially totally relieve the brake pressure, the improvement wherein said system is constructed and arranged so that pressures in said conduit of intermediate values between said two pressure values produce correspondingly intermediate brake pressure values, said skid control device being directly responsive to the speed of the wheel and adapted to effect a governor action to open said conduit to said first passage at normal operating wheel speeds and open said conduit to said second passage at substantially slower wheel speeds, upon the occurrence of a skid condition during braking, said skid control device adapted, due to its governor action, to connect said conduit with said second passage until the conduit pressure reaches an intermediate release level at which said wheel increases speed and thereupon, in a rapid, repeated hunting movement to alternately connect said conduit to

said first and second passages whereby said conduit pressure can first be caused to change from said first pressure to said intermediate relief pressure, and then to change in a modulating manner about said release pressure as a mean , without returning to said first pressure.

12. The apparatus of claim 11 wherein said first and second pressures are gas pressures and said first passage is open to the atmosphere whereby normal operation of the brakes is ensured during a skid condition should the power source for said second pressure fail.

13. The apparatus of claim 12 wherein said second pressure is a vacuum, the wheel brake is operated by a hydraulic pressure line and the pressure in said line is controlled during skid conditions by a piston device responsive to vacuum, said piston having a small hydraulic pressure piston portion disposed in a corresponding cylinder, adapted to relieve and apply hydraulic pressure at the brakes, and a relatively very large piston portion disposed in a corresponding cylinder exposed to the gas pressure of said conduit, at least some of the area of the opposite side of said large piston being vented to atmosphere, and spring means biasing said piston device in the direction to apply hydraulic pressure.

14. The apparatus of claim 11 for use in a closed circuit hydraulic system actuated by a master cylinder, having an isolation valve between said master cylinder and said wheel brake and a variable volume cylinder responsive to said conduit pressure for varying said hydraulic pressure at said wheel brake, wherein said modulating conduit pressure is adapted to correspondingly modulate said variable volume of said cylinder and means are provided to maintain said isolation valve closed throughout the period while said conduit modulates the volume of said cylinder and thereby said hydraulic pressure.

15. The system of claim 11 wherein the movable member of said valve is rotary and comprises an elongated member, two bores extending generally diametrically through said member, located at different places along its length, each of said bores having an elongated cross-section in the direction of elongation of said member, said member being rotatable between one position where the supply side of one of said bores communicates with said first passage while the other bore is closed, and a second position where the supply side of the other of said bores communicates with said second passage while the other bore is closed, each of said bores discharging to said brake control conduit.

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16. The apparatus of claim 11 wherein said skid control device is a rotary weight governor, and means are provided to prevent the operation of said governor during normal operation of said brake pressure.

17. In an anti-skid apparatus for use in a brake system employing means normally controlling brake pressure to a vehicle wheel brake through a hydraulic pressure line, a separate relieving device adapted to relieve the brake pressure at the wheel brake and a control apparatus adapted to control said relieving device, said relieving device comprising an isolation valve adapted normally to be open but able to seal said wheel brake from the effect of said normal control means and means adapted to relieve the fluid pressure at said wheel brake, said isolation valve including a movable member adapted to seat to prevent pressure communication to said wheel brake, and said relieving means comprising a piston disposed in a hydraulic cylinder, said cylinder in communication with said hydraulic line at a location between said wheel brake and said isolation valve, ~~the improvement wherein~~ said piston being adapted to directly operate said isolation valve, said piston having a projection adapted to engage said movable member of said valve, to position said movable member in an unseated position and to allow said member to seat dependent upon the position of said piston, said piston being movable beyond the position at which said member is allowed to seat, to relieve pressure at said wheel brake when said isolation valve is in sealing position, said control device adapted to regulate the position of said piston variably in accordance with skid conditions while said movable member is seated.

18. The apparatus of claim 17 wherein said piston is biased by a spring to position said movable member in the unseated position, in a manner to perform a pressure limiting function, said spring having a predetermined effective force that is less than the maximum force that can be applied oppositely on said member by said normal hydraulic pressure, whereby, when said maximum hydraulic pressure is applied, said spring can yield even when skid conditions do not exist, to allow said movable member to seat, to prevent said maximum pressure from being communicated to said wheel brake thereby limiting the amount of brake pressure that must be relieved when a skid condition occurs.

~~19.~~ 20. In an anti-skid system adapted to relieve fluid pressure applied by an operator to ~~a wheel~~ the brake for a vehicle wheel on the occurrence of skid conditions, the improvement comprising a resiliently loaded fluid pressure limiting device connected to the fluid pressure line and constructed and arranged to limit the pressure normally applied by the operator to the wheel brake to a predetermined maximum level, said level being less than the full pressure applicable by the operator, whereby, as a skid condition occurs when the operator jams on his brakes to the full extent, said anti-skid system is able to stop the skid without having to relieve the full pressure applied by the operator.

20. For use in an anti-skid system for controlling motor vehicle brakes of the type having brake actuators associated with the wheels of the vehicle, said actuators causing the brakes of the vehicle to be applied in response to introduction of fluid under pressure to said actuators, and a master cylinder having a fluid supply therein and means for causing said fluid to be forced from said master cylinder to normally control the application of said wheel brakes, a brake pressure control device, said control device comprising a cylinder and piston, means responsive to the introduction of atmosphere to one side of said piston for enabling pressure to be applied to said brake actuators, and means responsive to the introduction of vacuum to one side of the piston for automatically preventing said master cylinder from influencing said brake actuators and relieving the pressure at said actuators, a valve controlling said control device, said valve movable between first and second positions, said valve at said first position supplied with atmospheric pressure at least whenever said master cylinder is activated, whereby only atmosphere can be introduced to said cylinder by said valve when said valve is in said first position, said valve at said second position supplied with suction, means normally maintaining said valve in said first position, at least whenever said master cylinder is activated, means responsive to the presence of a skid condition for automatically moving said valve to said second position to apply suction to said system, and said system adapted to establish direct communication between said master cylinder and said hydraulic actuators should the supply of vacuum fail.

21. The system of claim 20 further characterized in that the means for moving said valve comprises an anti-skid unit having a first shaft, a cam gear mounted on said first shaft and axially movable with respect thereto between a first and second position, means normally maintaining said cam gear in its said first position, a second gear in mesh with said cam gear, said second gear being driven by the vehicle drive train, a second shaft in axial alignment with said first shaft and axially movable with respect thereto between a first and second position, rotary weight governor means interconnecting said first and second shafts whereby the rotational speed of said first shaft will determine the axial position of said second shaft, the relation being such that as the speed of said first shaft decreases, said governor means will tend to move said second shaft to its said second position, retaining means normally maintaining said second shaft in its said first position and preventing its movement toward its second position, cam means responsive to a sudden slowing of said second gear for causing movement of said cam gear to its said second position, actuator means responsive to movement of said cam gear to its said second position for rendering said retaining means inoperative, and means maintaining said retaining means inoperative for a predetermined interval after said cam gear has returned to its said first position, said valve being operatively connected to said second shaft whereby axial movement of the latter causes movement of the former.

22. The system of claim 21 further characterized in that said valve means comprise a rotary valve, and a projection extending from said rotary valve into engagement with said second shaft, whereby axial movement of the latter causes rotation of the former.

23. For use in an automotive brake system employing a brake pedal and master cylinder to normally control brake pressure at a vehicle wheel brake, sensing means to sense a skid condition, control means responsive to said sensing means and employing vacuum produced by said vehicle as a power source, said control means adapted to relieve the pressure of the brakes, and means responsive to loss of said vacuum adapted to place said master cylinder in direct communication with said wheel brake.

24. The apparatus of claim 23 wherein said relieving means is incorporated in a power unit adapted to apply brake pressure in response to said brake pedal, said power unit constructed to prevent any direct communication between the brake pedal pressure and the wheel brakes when said engine is operating, and a two-position valve adapted at one position to connect said brake pedal pressure to control said power unit and connect said power unit with said wheel brake, and at the other position to connect said brake pedal pressure directly with said wheel brake, by-passing said power unit, means causing the vacuum of said engine to maintain said valve in said first position, and means responsive to loss of said vacuum to move said valve to said second position.

25. An anti-skid device comprising a valve for controlling the relief and application of brake pressure, and control means responsive to skid conditions for actuating said valve, said control means capable of producing only a limited actuating movement and said valve comprising a rotary valve member adapted to alternately connect a brake control conduit to first and second passages maintained at different fluid pressures, said valve member comprising an elongated rod, first and second axially spaced-apart passageways through said rod, each of said passageways having a cross-section elongated in the axial direction of a length exceeding the diameter of said rod, said rod in one position adapted to connect said conduit with said first passage while sealing said second passage, and in a second rotary position adapted to connect said conduit with said conduit with said second passage while sealing said first passage and means connecting said valve member for rotary movement between said positions in response to said actuating movement of said control means.

26. In a wheel brake anti-skid unit comprising a governor and an inertia-responsive means controlling the action of said governor, said governor having a drive shaft and said inertia-responsive means including a drive member mounted on said shaft, driven dependently with the speed of the wheel and arranged to drive said governor, while allowing said governor to rotate a limited amount relative thereto due to the inertia of said governor when said drive member changes speed, and means actuated by said relative movement on deceleration of said drive member to activate said governor, the improvement wherein one of said shaft and drive member has a radially extending projection and the other has two arcuately spaced-apart stop surfaces that are adapted to engage said projection one when accelerating torque and the other when decelerating torque is to be applied to said governor by said drive member, the spacing between said stop surfaces allowing relative rotary movement of said projection from one stop surface to the other, and means exerting a predetermined torque to urge said projection into contact with the stop surface that is engaged when accelerating torque is applied to said governor to limit the freedom of said projection from moving to the other stop surface.

~~27.~~ 13. An anti-skid unit for pressure actuated vehicle brakes comprising a pair of aligned shafts, means connecting said shafts for rotation as a unit with one of said shafts axially movable with respect to the other, governor means connected to said shafts, said governor means being adapted to cause movement of said axially movable shaft in response to variations in rotational speed of said shafts, drive means operative in response to rotation of the vehicle wheels for imparting corresponding rotation to said shafts, valve means movable between a first position wherein said vehicle brakes may be applied and a second position wherein said brakes are automatically released, means controlling movement of said valve means in response to axial movement of said axially movable shaft, a normally deenergized solenoid having a plunger that maintains said axially movable shaft against axial movement and in a position wherein said valve means is in its said first position, and means for energizing said solenoid to retract said plunger and release said axially movable shaft for axial movement under the control of said governor means, said energizing means comprising a first switch, cam means automatically actuating said first switch in response to sudden slowing of said vehicle wheels and said drive means, and a second switch automatically actuated by the solenoid plunger when the latter is retracted to maintain the solenoid energized after said first switch opens.

~~28.~~ 14. The anti-skid unit of claim ~~27~~ 13 further characterized in that said energizing means comprises a third switch, said third switch being closed by the presence of fluid pressure in the system, said solenoid remaining energized until fluid pressure in the system drops below the predetermined value to open said third switch.

27. The anti-skid unit of claim 21 further characterized in that resilient means are provided for urging said solenoid plunger into frictional engagement with said axially movable shaft when the solenoid is deenergized, thereby imparting a frictional drag to said axially movable shaft during rotation thereof, and stop means limiting the extent of movement of said plunger toward said shaft so as to prevent engagement therewith at relatively high rotational speeds due to axial movement of said shaft to a position out of the range of said plunger by said governor means.

30. A braking system for motor vehicles of the type wherein pressure actuators are located adjacent the wheels of the vehicle, said actuators causing the brakes of the vehicle to be applied in response to introduction of fluid under pressure to said actuators, said system comprising a master cylinder having a fluid supply therein and means for causing fluid to be pumped from said master cylinder, a direct line intercommecting said master cylinder and said actuators, a valve in said line, movable between a first position wherein the line is open, thus allowing the vehicle's brakes to be operated by said pumping means, and a second position wherein said line is blocked to remove control of said brakes from said pumping means, resilient means adapted to urge said valve to its said second position, movable control means normally maintaining said valve in its said first position, said control means comprising a cylinder and piston, means responsive to the introduction of atmosphere to one side of said piston for moving same to a first position, maintaining said valve in its said first position and means responsive to the introduction of suction to said one side of said piston for moving same to a second position permitting said valve to move to its said second position under the influence of said resilient means, means relieving fluid pressure on said actuators when said control means and valve are in their aforesaid second positions, and an anti-skid unit having means normally introducing atmosphere to said one side of said piston, said unit further comprising means automatically responsive to the presence of a skid condition created by sudden slowing of the vehicle wheels to block the flow of atmosphere to said one side of said piston and to introduce suction thereto.

31. The system o
anti-skid unit comprises a
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a second gear in mesh with
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shaft and axially movabl- w
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its said second position, r
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means responsive to movement
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32. The system o
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plunger of the latter to ino
automatically actuated in re
electric circuit also compri

presence of predetermined fluid pressure in the brake system to close said circuit, said pressure switch and said maintaining means functioning to maintain said circuit energized until the fluid pressure in the system falls below said predetermined value.

33. A power brake system for motor vehicles comprising a plurality of hydraulic brake actuators, a master cylinder having a fluid supply therein, means for causing fluid to be pumped from said master cylinder, a power brake unit having a first cylinder and piston means dividing said cylinder into vacuum and pressure chambers, a source of vacuum connected to said vacuum chamber, a first conduit extending from said vacuum chamber to said pressure chamber, a control valve movable between a first position wherein suction from said vacuum side is free to communicate with said pressure chamber to evacuate same and a second position wherein atmospheric pressure is introduced to said conduit for entry to said pressure chamber, resilient means operative to bias said first piston to a first position when both chambers are evacuated, said first piston being movable to a second position against the action of said resilient means when atmospheric pressure is introduced to said pressure chamber, means for moving said control valve between its first and second positions in response to the pumping of fluid from said master cylinder, a second cylinder and piston, said second cylinder having a supply of fluid therein, a line connecting said second cylinder to said brake actuators whereby actuation of said second piston forces fluid under pressure to said brake actuators to operate same, means connecting said first and second pistons whereby movement of said first piston from its first to second position causes actuation of said second piston, a line connecting said second cylinder to said master cylinder, whereby the suction created by actuation of said second piston automatically draws fluid into said second cylinder from said master cylinder, and a one-way valve in said second piston for allowing fluid to pass therethrough as said second piston returns to its inoperative position, thereby insuring at all times an adequate supply of fluid in said second cylinder.

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24. A control system for operating a vehicle wheel brake-relieving device for the purpose of preventing skids, said control system comprising the combination of an inertia-responsive means adapted to respond to a sudden decrease in the speed of rotation of the wheel and thereupon to initiate the operation of said relieving device, a rotary governor means adapted to rotate dependently with the speed of the wheel and adapted after said operation is initiated by said inertia-responsive means to correspondingly vary the condition of said relieving device, to decrease and increase the brake pressure dependently with decrease and increase in the speed of the wheel, a reset means adapted to respond to a predetermined, decreased speed of the vehicle, to terminate the operation of said relieving device, and reset said inertia-responsive means so that it may again initiate said operation, and means responsive to reverse rotation of the vehicle drive shaft for preventing operation of said control system.

Cl 17

25. The system of claim 16 further characterized in that said last-mentioned means comprises a switch that is automatically closed when the vehicle drive shaft is rotating in a forward direction and which automatically opens when the vehicle drive shaft rotates in a reverse direction.

36. A skid control system for a pressure-operated vehicle wheel brake, the pressure at said brake normally controlled by the driver of the vehicle, said control system comprising an anti-skid means adapted, on the occurrence of a skid condition during braking, to repeatedly decrease the pressure at the vehicle wheel brake dependently with decrease in the speed of the wheel, a pressure-sensitive switch set to detect the decrease of the pressure at the wheel brake to a predetermined minimum level, and thereupon remove the influence of said anti-skid means and return to normal control the pressure at said wheel brake, and a switch in said system controlled by the direction of rotation of the vehicle drive shaft, said switch automatically being closed when the vehicle drive shaft is rotating in a forward direction and automatically being open when the drive shaft is rotating in reverse, and means responsive to opening of said switch for preventing operation of said control system.

37. An anti-skid unit for pressure actuated vehicle brakes comprising a pair of aligned shafts, means connecting said shafts for rotation as a unit with one of said shafts axially movable with respect to the other, governor means connected to said shafts, said governor means being adapted to cause movement of said axially movable shaft in response to variations in rotational speed of said shafts, drive means operative in response to rotation of the vehicle wheels for imparting corresponding rotation to said shafts, valve means movable between a

first position wherein said vehicle brakes may be applied and a second position wherein said brakes are automatically released, means controlling movement of said valve means in response to axial movement of said axially movable shaft, a normally deenergized solenoid having a plunger that maintains said axially movable shaft against axial movement and in a position wherein said valve means is in its said first position, and means for energizing said solenoid to retract said plunger and release said axially movable shaft for axial movement under the control of said governor means, said energizing means comprising a first switch, cam means automatically actuating said first switch in response to sudden slowing of said vehicle wheels and said drive means, and a reverse switch in series with said first switch, operation of said reverse switch being controlled by the direction of rotation of the vehicle drive shaft, means automatically closing said reverse switch when the vehicle drive shaft is rotating in a forward direction, and means automatically opening said reverse switch when the drive shaft is rotating in reverse to thereby prevent energization of said solenoid.

38. A skid control system for a pressure-operated vehicle wheel brake, the pressure at said brake normally controlled by the driver of the vehicle, said control system comprising an anti-skid means adapted, on the occurrence of a skid condition during braking, to repeatedly decrease the pressure at the vehicle wheel brake dependently with decrease in the speed of the wheel, and switch means controlled by the direction of rotation of

the vehicle drive shaft for preventing operation of said control system when the drive shaft is rotating in reverse.

~~35~~ 19. The system of claim ~~36~~ 18 further characterized in that said switch means comprises a rotatable shaft drivingly interconnected to the vehicle drive shaft, a contact button adapted to resiliently engage one end of the rotatable shaft, said rotatable shaft being axially movable between a first position wherein it is in engagement with said button and a second position wherein it is disengaged therefrom, and cam means associated with said rotatable shaft for automatically causing axial movement thereof to said first position when the vehicle drive is in forward, and for automatically causing movement thereof to said second position when the vehicle drive is in reverse.

40. An electric switch movable automatically to an open position in response to rotation of a shaft in one direction and movable automatically to a closed position in response to rotation of the shaft in the opposite direction, said switch comprising a rotatable shaft, a contact button adapted to resiliently engage one end of said shaft, means mounting said shaft for axial movement between a first position wherein said contact button is in engagement with said shaft and a second position wherein it is disengaged therefrom, and cam means associated with said shaft for automatically moving said shaft to said first position when the shaft is rotating in one direction and to the said second position when the shaft is rotting in the opposite direction.

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[PX 150, p 66]

S298—APPLICATION FOR UNITED STATES PATENT

JULIUS BLUMBERG, INC., LAW BLANK PUBLISHERS
80 EXCHANGE PLACE AT BROADWAY, NEW YORK

SOLE

Oath, Power of Attorney, and Petition

Being duly sworn, I, Frank A. Perrino

depose and say that I am a citizen of United States of America residing at North Attleboro, County of Bristol and State of Massachusetts; that I have read the foregoing specification and claims and I verily believe I am the original, first, and sole inventor of the invention or discovery in BRAKING SYSTEM AND ANTI-SKID MEANS THEREFOR

described and claimed therein; that I do not know and do not believe that this invention was ever known or used before my invention or discovery thereof, or patented or described in any printed publication in any country before my invention or discovery thereof, or more than one year prior to this application, or in public use or on sale in the United States for more than one year prior to this application; that this invention or discovery has not been patented in any country foreign to the United States on an application filed by me or my legal representatives or assigns more than twelve months before this application; and that no application for patent on this invention or discovery has been filed by me or my representatives or assigns in any country foreign to the United States, except as follows:

And I hereby appoint Salter & Michaelson, of 146 Westminster Street, Providence, Rhode Island 02903

Registration No. 19,585, my attorney or agent with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith.

Wherefore I pray that Letters Patent be granted to me for the invention or discovery described and claimed in the foregoing specification and claims, and I hereby subscribe my name to the foregoing specifications and claims, oath, power of attorney, and this petition, this

29th day of October, 1964

Inventor Frank (First name) A. (Middle initial) Perrino (Last name)

Post Office Address { 345 East Washington Street
North Attleboro, Massachusetts

State of Rhode Island
County of Providence } ss

Before me personally appeared Frank A. Perrino to me known to be the person described in the above application for patent, who signed the foregoing instrument in my presence, and made oath before me to the allegations set forth therein as being under oath, on the day and year aforesaid.

[SEAL]

Elliot A. Salter
Notary Public

This form may be executed only when attached to a complete application as the last page thereof

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Approved Single Sheet Form Under Revision

[PX 150, p 66]

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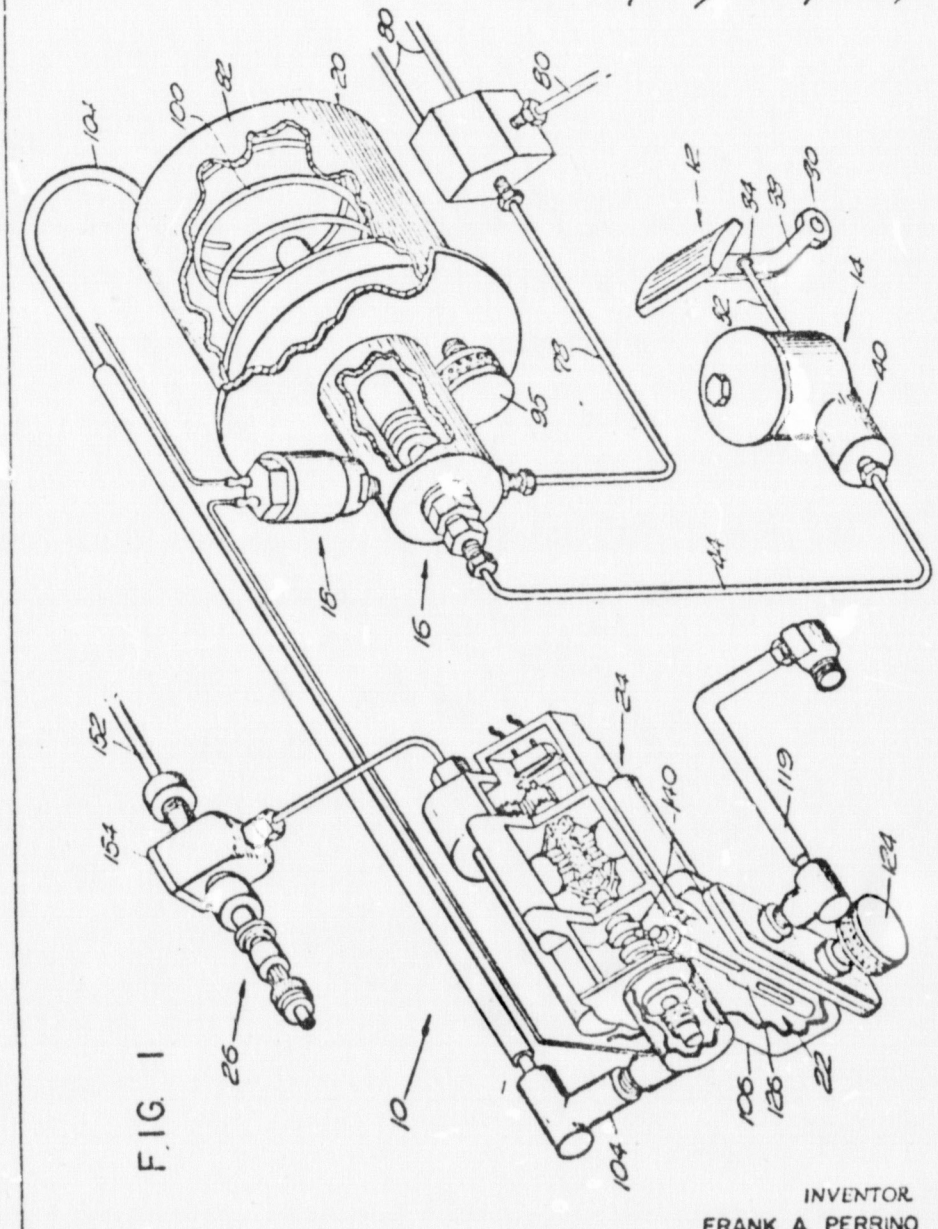

FIG. 1

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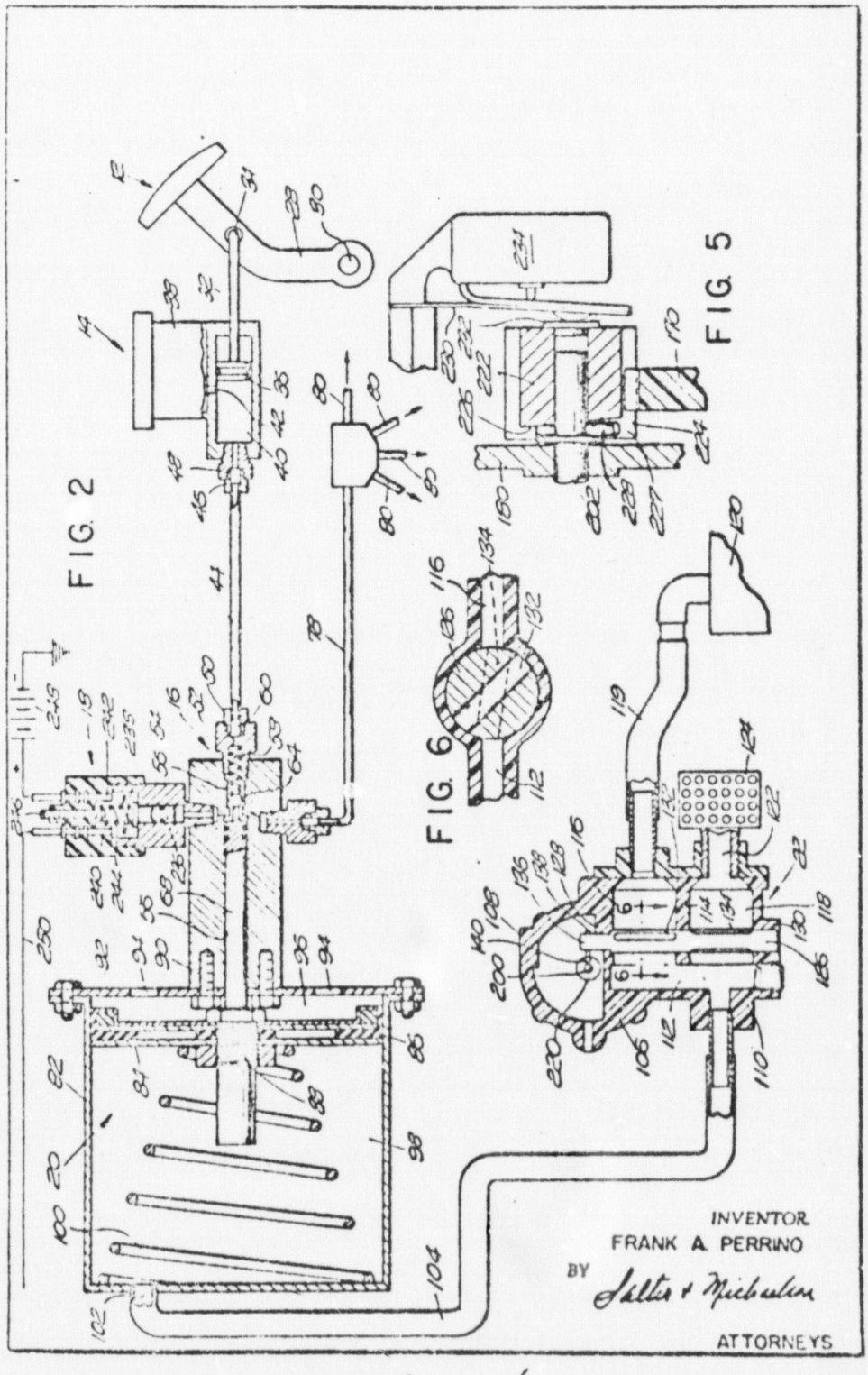

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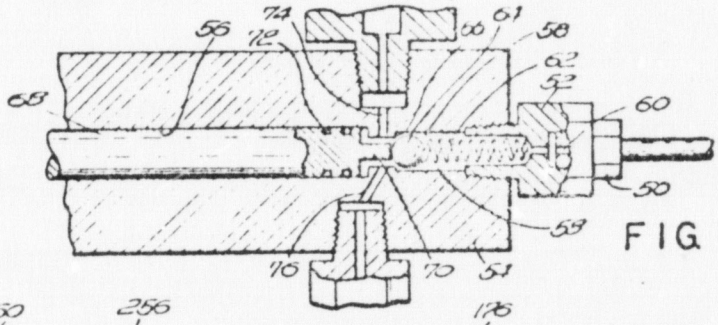
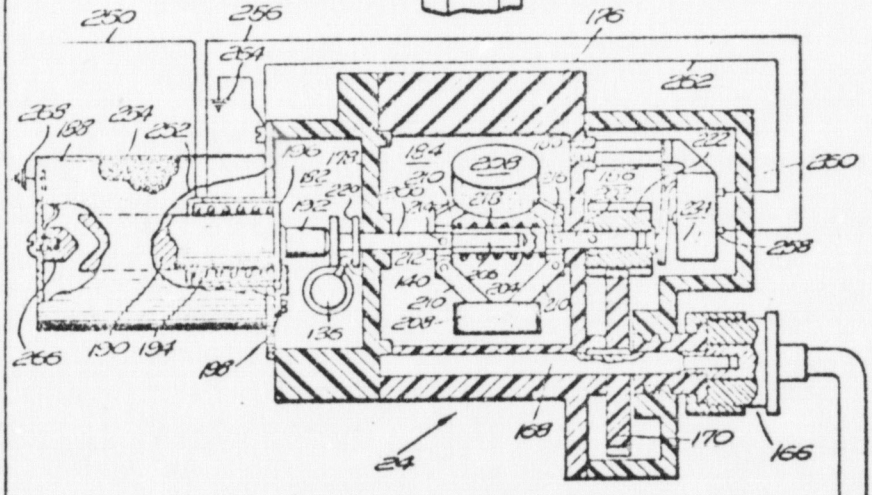


FIG. 3



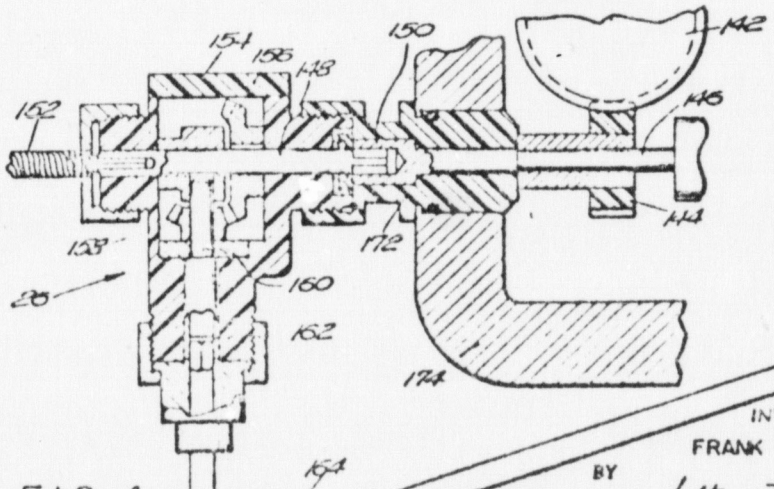


FIG. 4

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[PX 150, p 69]

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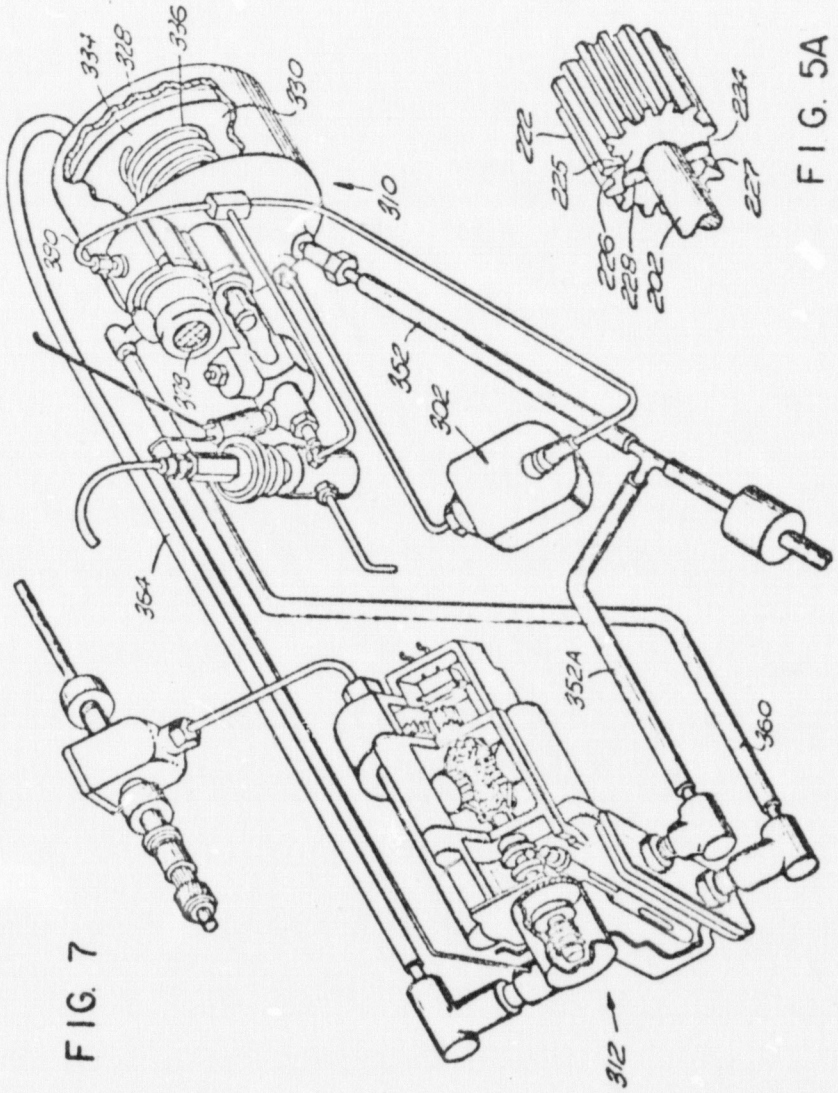

FIG. 5A

FIG. 7

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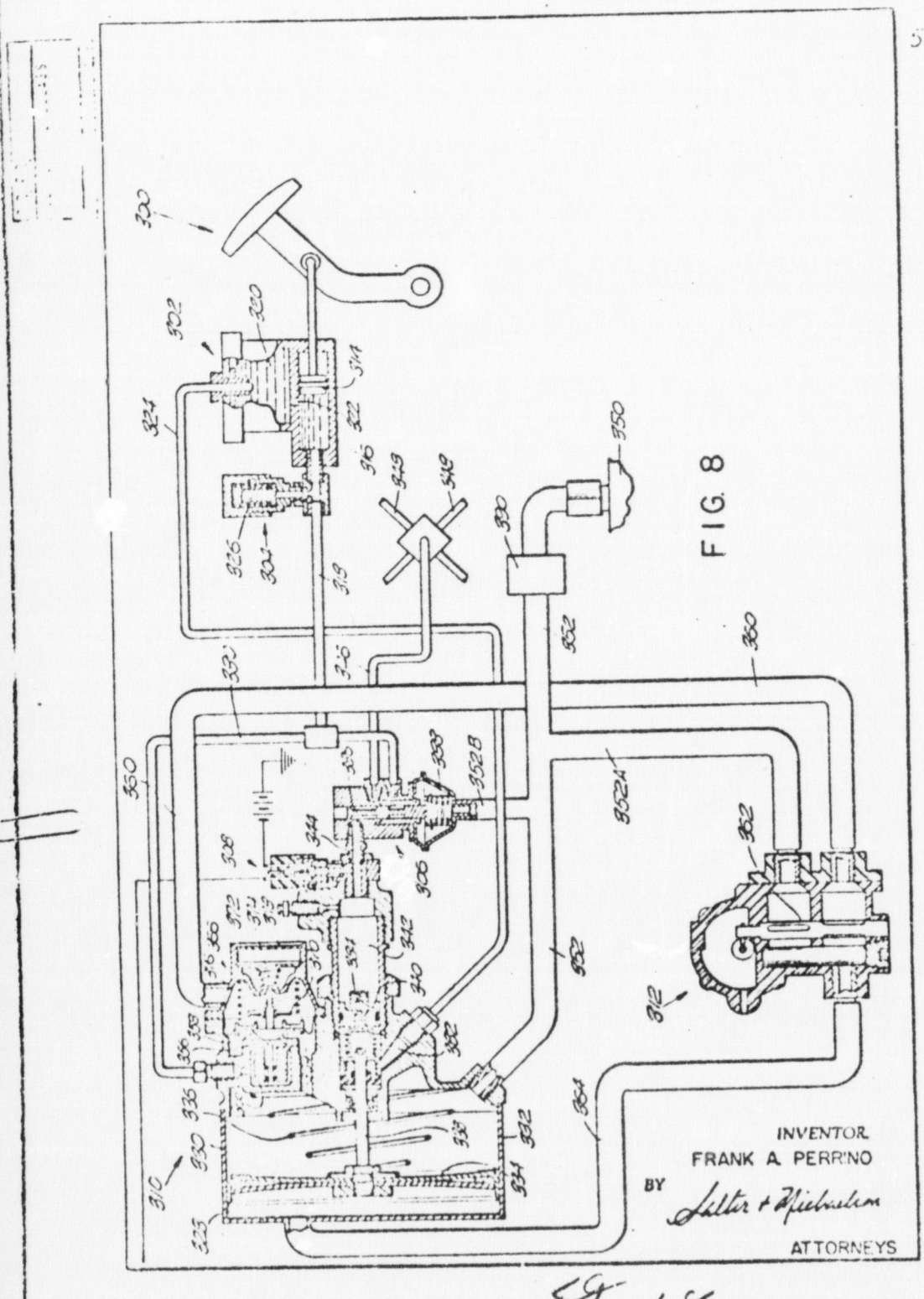

FIG. 8

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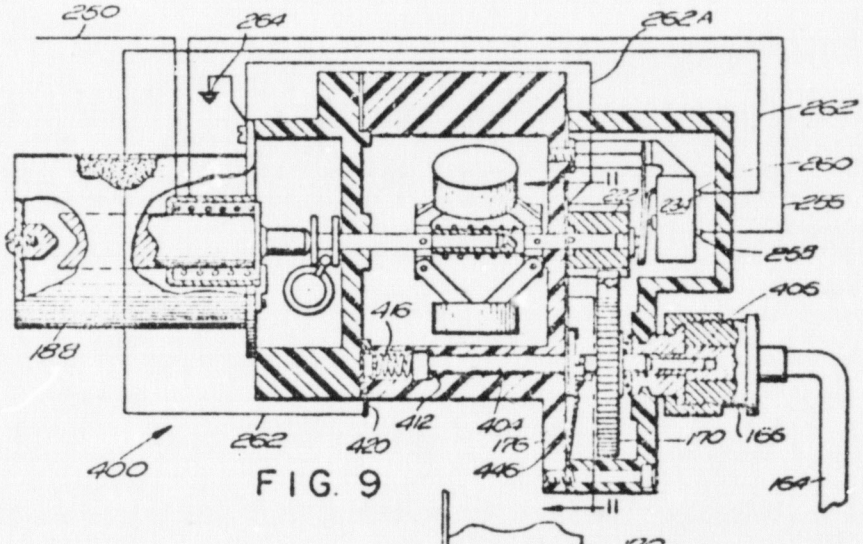

FIG. 9

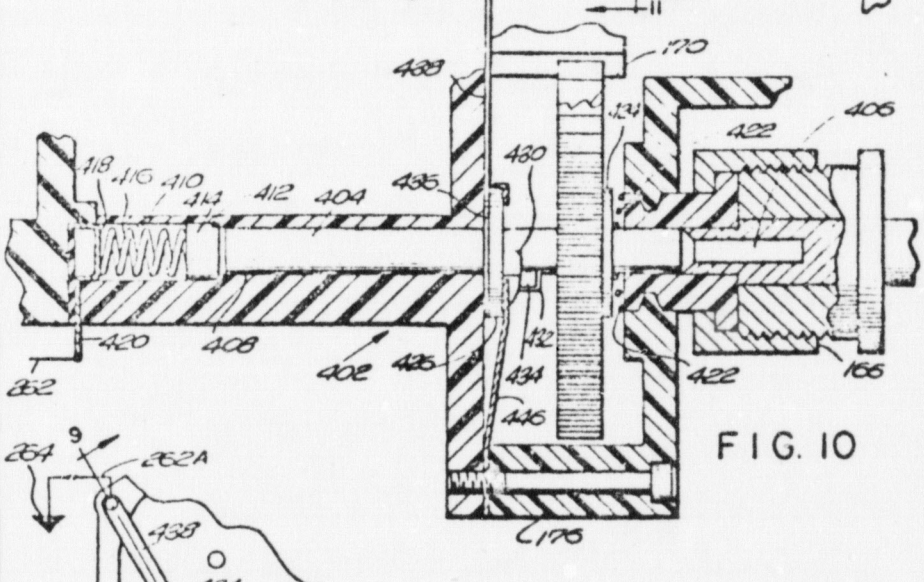

FIG. 10

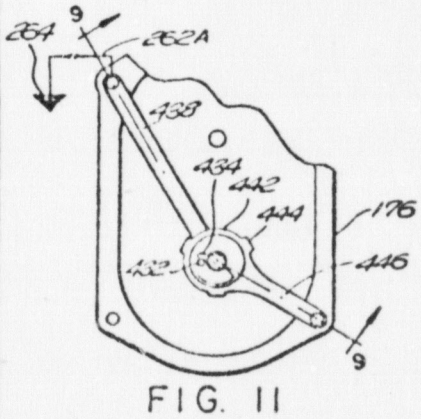

FIG. 11

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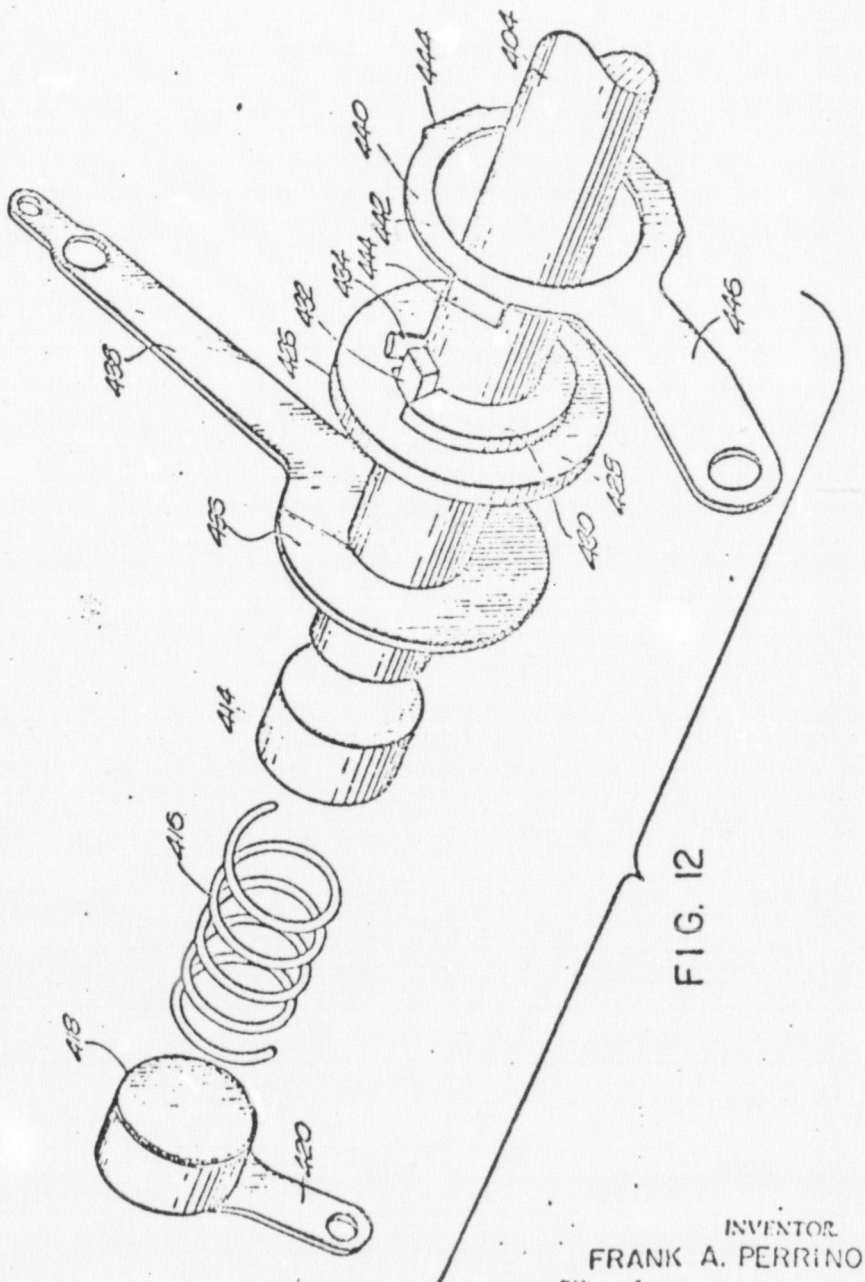

FIG. 12

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[PX 150, p 73]

PLAINTIFF'S EXHIBIT 154 (AT 23)

B. Front brakes are applied on start up or [illegible] maximum braking condition. (Also see Brake Warning Light "ON", condition "D").	[illegible]	Replace broken leads. Crimp sleeves at ends of new leads as in plug "A" and "D". (Color code Plug "A" Red Blue Black, plug "D" Green Blue).
	Faulty module or loose electrical connection.	Remove plug "A" (color code: Red-Blue-Black) from module. Refer to Figure 14. Connect an ohmmeter between system ground plug sleeve (black) and suitable chassis ground. (Refer to Figure 18). If ohmmeter reading is less than one ohm, replace module and recheck system for normal operation. If reading is greater than one ohm, replace or repair system ground wire.
	Module component failure.	Replace module and perform functional check.
	Actuator component failure.	Replace actuator and perform functional check.
C. No rear brakes	Faulty module. Faulty actuator.	Replace module. Replace actuator.
D. Actuator cycles slowly during a maximum braking condition.	Plugged actuator air filter or punched actuator air or vacuum hose.	Check and clean filter or air or vacuum hoses as required.
	Faulty actuator.	Replace actuator.

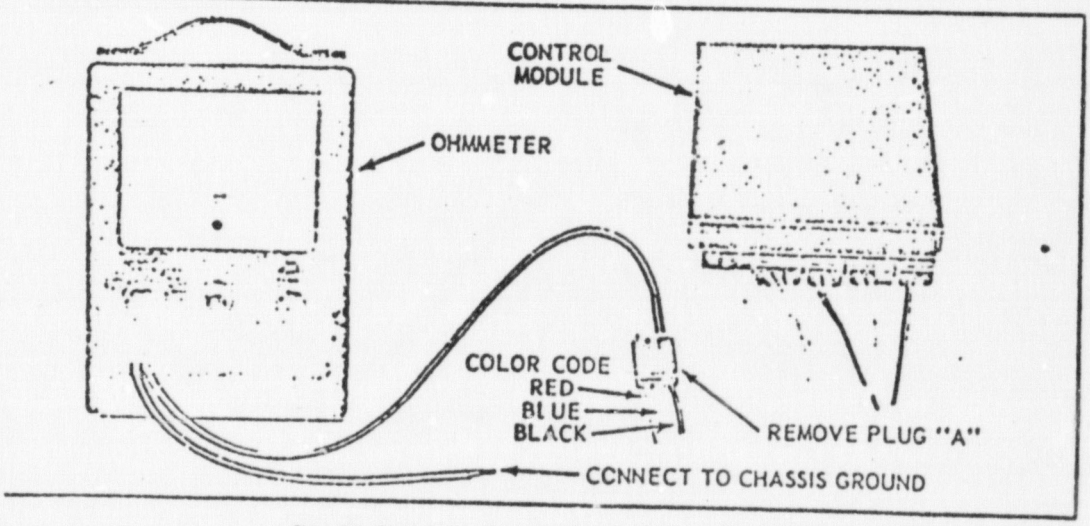

Fig. 18- Testing Module and System Ground

BRAKES

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DRUM BRAKES	5	SURE BRAKE	57
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SERVICE ADJUSTMENTS

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Brake Hose and Tubing	2	Wheel Stud Nut Tightening	2
Stop Lamp Switch Adjustment	4		

ADJUSTING SERVICE BRAKES

Normally self adjusting brakes will not require manual adjustment but in the event of a brake reline it may be advisable to make the initial adjustment manually to speed up the adjusting time.

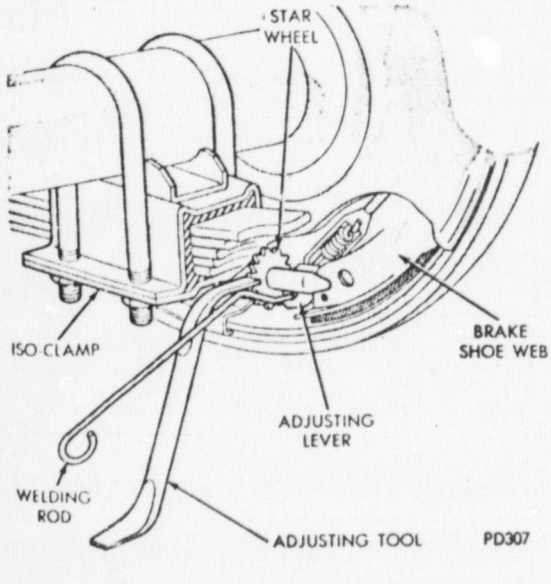

Fig. 1 - Adjusting Brakes (Rear-with Iso-Clamp)

(1) Jack up vehicle so all wheels are free to turn.

(2) Remove rear adjusting hole cover from brake supports of vehicle.

(3) **Be sure parking brake lever is fully released, then back off parking brake cable adjustment so there is slack in cable.**

(4) Insert adjusting tool C-3784, into star wheel of adjusting screw. Move handle of tool upward until a slight drag is felt when road wheel is rotated.

(5) Insert a thin screwdriver or piece of welding rod into brake adjusting hole and push adjusting lever out of engagement with star wheel (models with Iso-Clamp rear suspension, bend welding rod to match adjusting tool angles plus a 3/4 reverse bend at contact end), (Fig. 1). **Care should be taken so as not to bend adjusting lever or distort lever spring.** While holding adjusting lever out of engagement, back off star wheel to insure a free wheel with no brake shoe drag.

(6) Repeat above adjustment at each wheel. The adjustment must be equal to all wheels. Install adjusting hole covers in brake supports.

(7) Adjust parking brake **after** wheel brake adjustment.

It is important to follow the above sequence to avoid the possibility of the parking brake system causing brake drag as may occur if the parking brakes are adjusted before the service brakes.

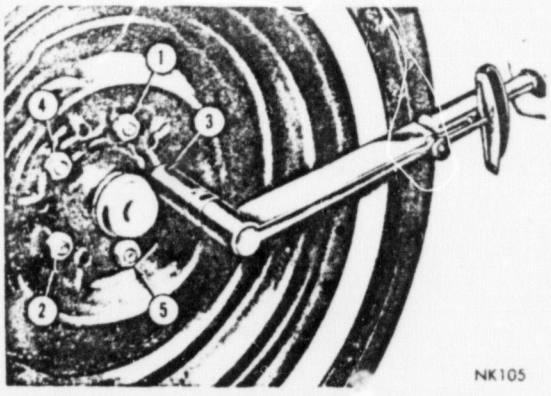

Fig. 2 - Wheel Stud Nut Tightening Sequence

TESTING APPLICATION ADJUSTER OPERATION

Place the vehicle on a hoist, with a helper in the driver's seat to apply the brakes. Remove the plug from the rear adjustment slot in each brake support plate to observe the adjuster star wheel. Then, to exclude the possibility of maximum adjustment; that is, the adjuster refuses to operate because the closest possible adjustment has been reached; the star wheel should be backed off approximately 30 notches. It will be necessary to hold the adjuster lever away from the star wheel to allow backing off of the adjustment.

Spin the wheel and brake drum in the reverse direction and apply the brakes vigorously. This will provide the necessary inertia to cause the secondary brake shoe to leave the anchor. The wrap up effect will move the secondary shoe, and the cable will pull the adjuster lever up. Upon application of the brake pedal, the lever should move upward, turning the star wheel. Thus, a definite rotation of the adjuster star wheel can be observed if the automatic adjuster is working properly. If by the described procedure one or more adjusters do not function properly, the respective drum must be removed for adjuster servicing.

BLEEDING BRAKE SYSTEM

Clean all dirt and foreign material from the cover of the master cylinder to prevent any dirt from falling into the master cylinder reservoir when the cover is removed.

Using the one man bleeder tank C-3496-B (with adapter) provides a convenient means of keeping the master cylinder full while pressurizing the hydraulic system for bleeding. (Complete bleeding of the dual master cylinder is important! See Bleeding the Master Cylinder in this Group.) **Manual Bleeding is not recommended because of reduced fluid flow. (For Floating Caliper Disc Brakes see "Hydraulic System Control Valves", this Group)**

Tighten the brakes of each wheel until the brakes are locked. (This reduces the movement of the wheel cylinder cups and assists in bleeding).

Starting with the right rear wheel clean all dirt from the bleeder valve. Place bleeder hose C-4029 on the bleeder valve and insert the other end of the bleeder hose into a clear jar half filled with clean brake fluid. (This will permit the observation of air bubbles as they are being expelled from the hydraulic system and also prevent air from being drawn back into the system. Follow the manufacturers instructions in the use of the bleeder tools.)

Continue this bleeding operation on the other wheels, starting with the left rear wheel, then the right front and finishing with the left front wheel.

If necessary, repeat this bleeding operation if there is any indication (a low, soft or spongy brake pedal) of air remaining in the hydraulic system. Readjust the brakes as described previously.

TEST FOR FLUID CONTAMINATION

To determine if contamination exists in the brake fluid (as indicated by swollen or deteriorated rubber cups), the following test can be made.

Place a small amount of the drained brake fluid into a small clear glass bottle. Separation of the fluid into distinct layers will indicate mineral oil content.

If there is any question of mineral oil content, as indicated by swollen or deteriorated rubber parts, drain and flush thoroughly and replace all rubber parts.

WHEEL STUD NUT TIGHTENING

The tightening sequence and torquing of the wheel stud nuts is of great importance to insure efficient brake operation. The use of an impact or long handled wrench may distort the drum.

A criss-cross tightening sequence should be used (Fig. 2). Tighten all the stud nuts to one-half the specified torque first, (30 ft. lbs.), and then repeat the sequence tightening to the specified 55 foot-pounds. (65 foot pounds on 10 and 11 inch brakes).

BRAKE HOSE AND TUBING

Installation of Brake Hose

The flexible hydraulic brake hose should **always** be installed on the vehicle by first tightening the male end of the hose into caliper, wheel cylinder, or rear axle housing tee. The hose should then be attached to the hose bracket in a manner to give minimum twist. (15 degree twist is the maximum recommended). Excessive twist can result in hose interference problems with possible hydraulic system failure.

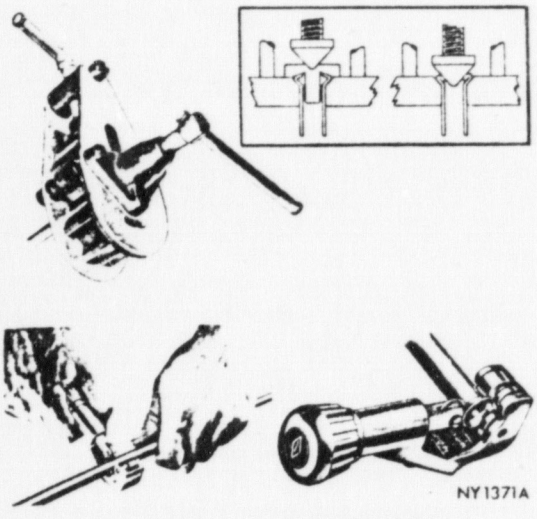

Fig. 3 - Cutting and Flaring Steel Tubing

Inspection of Brake Hose and Tubing

Inspection of brake hose and tubing should be included in all brake service operations and every 6 months or 6,000 miles (every 3 months or 4,000 miles for vehicles used in fleet service; Police, Taxi, etc.). The hoses should be checked for:

(1) Correct length, severe surface cracking, pulling scuffing or worn spots. **(Should the fabric casing of the hose be exposed by cracks or abrasions in the rubber hose cover, the hose should be replaced).** Eventual deterioration of the hose can take place with possible burst failure.

(2) Faulty installation to cause twisting, wheel, tire or chassis interference.

Always use factory recommended hose to insure quality, correct length and superior fatigue life. Care should be taken to make sure that the tube and hose mating surfaces are clean and free from nicks and burrs. New copper seal washers should be used and the tube nuts and connections should be properly made and tightened. Double wall steel tubing should always be used to insure superior fatigue life. Care should be taken when replacing brake tubing, to use the proper bending and flaring tools and to avoid routing the tubes against sharp edges, moving components or in hot areas. All tubes should be properly attached with recommended retaining clips.

Steel tubing is used to conduct hydraulic pressure to the front and rear brakes. Flexible rubber hose is used at both front brakes and at a rear axle junction block. Steel tubing is used from the junction block to both rear wheel cylinders. All fittings, tubing and hoses should be inspected for rusted, damaged or defective flaring seats. The steel tubing is equipped with a double flare or inverted seat to insure more positive seating in the fitting. To repair or reflare tubing proceed as follows:

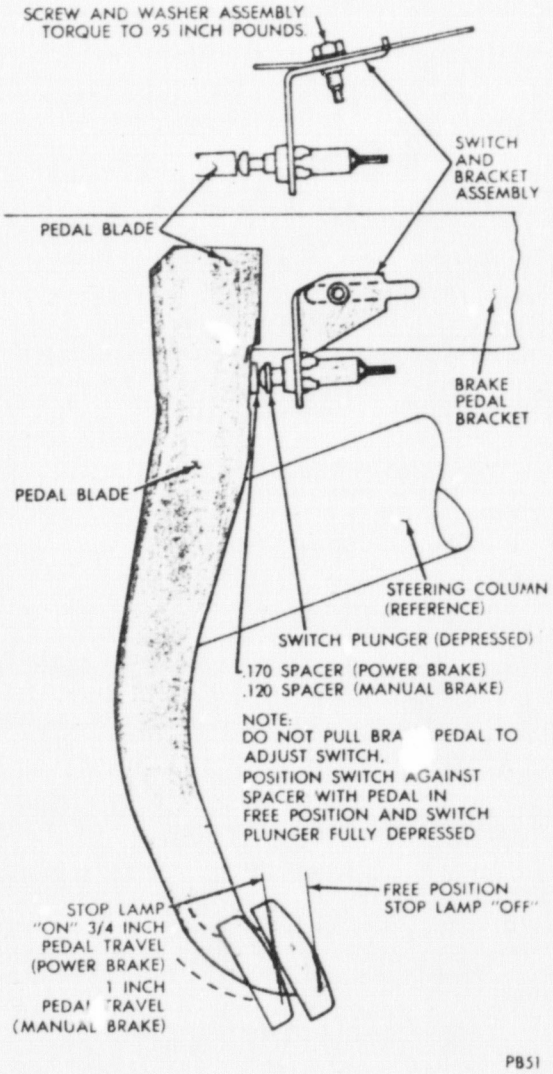

Fig. 4 - Stop Light Switch Adjustment (Valiant Models)

(1) Using Tool C-3478, or equivalent, cut off damaged seat or damaged tubing (Fig. 3).

(2) Ream out any burred or rough edges showing on inside edges of tubing. This will make the ends of tubing square and insure better seating of flared end tubing. **Place compression nut on tubing prior to flaring tubing.**

(3) To flare tubing open handles of flaring Tool C-4047 and rotate jaws of tool until the mating

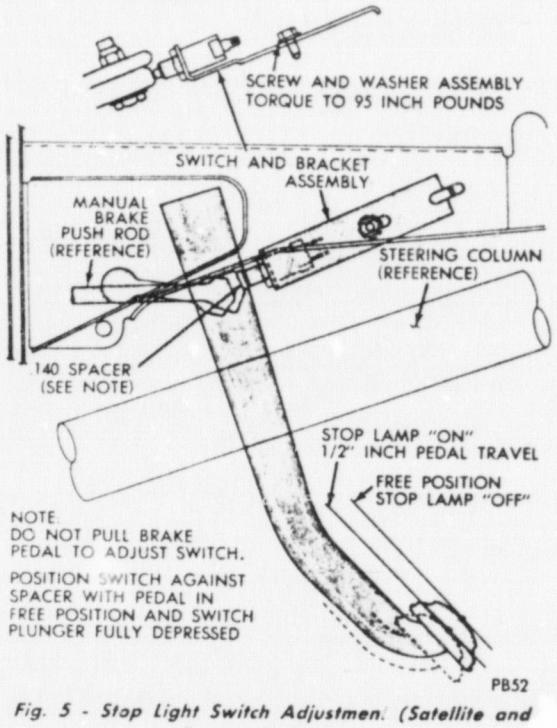

Fig. 5 - Stop Light Switch Adjustmen. (Satellite and Barracuda Models)

jaws of tubing size are centered in area between vertical posts.

(4) Slowly close handles with tubing inserted in jaws but do not apply heavy pressure to handle as this will lock tubing in place.

(5) Place gauge "Form A" on edge over end of tubing and push tubing through jaws until end of tubing contacts the recessed notch of gauge matching the size of tubing (Fig. 3).

(6) Squeeze handles of flaring tool and lock tubing in place.

(7) Place proper sized plug of gauge "A" down in end of tubing. Swing compression disc over gauge and center tapered flaring screw in recess of disc.

(8) Lubricate taper of flaring screw and screw in until plug gauge has seated on jaws of flaring tool. This action has started to invert the extended end of the tubing.

(9) Remove gauge and apply lubricant to tapered end of flaring screw and continue to screw down until tool is firmly seated in tubing.

(10) Remove tubing from flaring tool and inspect seat.

(11) Clean seat and tube of any lubricant before connecting to hydraulic system.

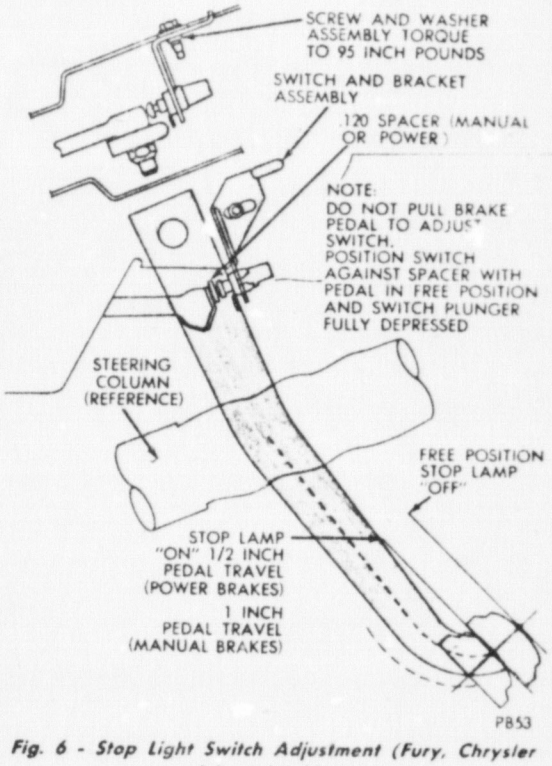

Fig. 6 - Stop Light Switch Adjustment (Fury, Chrysler and Imperial Models)

STOP LIGHT SWITCH ADJUSTMENT

The stop light (or stop light/speed control) switch and mounting bracket assembly is attached to the brake pedal bracket. The switch is actuated by the pedal blade on Valiant models and by the brake push rod on all other models.

Refer to figures 4, 5 or 6 for proper switch adjustment as follows:

(1) Loosen switch assembly to pedal bracket attaching screw and slide assembly away from pedal blade or brake push rod.

(2) Push brake pedal down and allow to return to free position, **do not pull brake pedal back at any time.**

(3) Place proper spacer gauge on pedal blade or push rod.

(4) Slide switch assembly toward pedal blade or push rod until switch plunger is fully depressed against spacer gauge (on heavy duty or stop light/speed control switches, depress plunger until switch body contacts spacer gauge).

(5) Re-tighten switch bracket screw to 95 inch pounds.

(6) Remove spacer.

DRUM BRAKES

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GENERAL INFORMATION

The new Models are equipped with servo contact, two shoe, internal expanding brakes with appliction adjusters. The lower ends of the brake shoes are connected by a tubular star wheel adjusting screw (Fig. 1).

DRUM BRAKES

SERVICE DIAGNOSIS

Condition	Possible Cause	Correction
PEDAL GOES TO FLOOR	(a) Fluid low in reservoir.	(a) Fill and bleed master cylinder.
	(b) Air in hydraulic brake system.	(b) Fill and bleed hydraulic brake system.
	(c) Improperly adjusted brake.	(c) Repair or replace self-adjuster as required.
	(d) Leaking wheel cylinders.	(d) Recondition or replace wheel cylinder and replace both brake shoes.
	(e) Loose or broken brake lines.	(e) Tighten all brake fittings or replace brake line.
	(f) Leaking or worn master cylinder.	(f) Recondition or replace master cylinder and bleed hydraulic system.
	(g) Excessively worn brake lining.	(g) Reline and adjust brakes.
SPONGY BRAKE PEDAL	(a) Air in hydraulic system.	(a) Fill master cylinder and bleed hydraulic system.
	(b) Improper brake fluid (low boiling point).	(b) Drain, flush and refill with brake fluid.
	(c) Excessively worn or cracked brake drums.	(c) Replace all faulty brake drums
	(d) Broken pedal pivot bushing.	(d) Replace nylon pivot bushing.
BRAKES PULLING	(a) Contaminated lining.	(a) Replace contaminated brake lining.
	(b) Front end out of alignment.	(b) Align front end.
	(c) Incorrect brake adjustment.	(c) Adjust brakes and check fluid.
	(d) Unmatched brake lining.	(d) Match primary, secondary with same type of lining on all wheels.
	(e) Brake shoes distorted.	(e) Replace faulty brake shoes.
	(f) Restricted brake hose or line.	(f) Replace plugged hose or brake line.
	(g) Broken rear spring.	(g) Replace broken spring.

5-6 DRUM BRAKES

SERVICE DIAGNOSIS

Condition	Possible Cause	Correction
SQUEALING BRAKES	(a) Glazed brake lining.	(a) Cam grind or replace brake lining.
	(b) Saturated brake lining.	(b) Replace saturated lining.
	(c) Weak or broken brake shoe retaining spring.	(c) Replace retaining spring.
	(d) Broken or weak brake shoe return spring.	(d) Replace return spring.
	(e) Incorrect brake lining.	(e) Install matched brake lining.
	(f) Distorted brake shoes.	(f) Replace brake shoes.
	(g) Bent Support Plate.	(g) Replace support plate.
	(h) Dust in brakes or scored brake drums.	(h) Blow out brake assembly with compressed air and reface brake drums.
CHIRPING BRAKES	(a) Out of round drum or eccentric axle flange pilot.	(a) Repair as necessary, and lubricate support plate contact areas (6 places).
DRAGGING BRAKES	(a) Incorrect wheel or parking brake adjustment.	(a) Adjust brakes and check fluid.
	(b) Parking brakes engaged.	(b) Release parking brakes.
	(c) Weak or broken brake shoe return spring.	(c) Replace brake shoe return spring.
	(d) Brake pedal binding.	(d) Free up and lubricate brake pedal and linkage.
	(e) Master cylinder cup sticking.	(e) Recondition master cylinder.
	(f) Obstructed master cylinder relief port.	(f) Use compressed air and blow out relief port.
	(g) Saturated brake lining.	(g) Replace brake lining.
	(h) Bent or out of round brake drum.	(h) Reface or replace faulty brake drum.
	(i) Incorrect stop light switch adjustment.	(i) Adjust stop light switch.
HARD PEDAL	(a) Brake booster inoperative.	(a) Replace brake booster.
	(b) Incorrect brake lining.	(b) Install matched brake lining.
	(c) Restricted brake line or hose.	(c) Clean out or replace brake line or hose.
	(d) Frozen brake pedal linkage.	(d) Free up and lubricate brake linkage.
WHEEL LOCKS	(a) Contaminated brake lining.	(a) Reline both front or rears of all four brakes.
	(b) Loose or torn brake lining.	(b) Replace brake lining.
	(c) Wheel cylinder cups sticking.	(c) Recondition or replace wheel cylinder.
	(d) Incorrect wheel bearing adjustment.	(d) Clean, pack and adjust wheel bearings.
BRAKES FADE (HIGH SPEED)	(a) Incorrect lining.	(a) Replace lining.
	(b) Overheated brake drums.	(b) Inspect for dragging brakes.
	(c) Incorrect brake fluid (low boiling temperature).	(c) Drain flush, refill and bleed hydraulic brake system.
	(d) Saturated brake lining.	(d) Reline both front or rear or all four brakes.
SURGE Below 15 MPH	(a) Bent or out of round rear brake drum.	(a) Reface or replace brake drum.
CHATTER 80 to 40 MPH	(a) Bent or out of round front brake drum.	(a) Reface or replace brake drum.
SHOE KNOCK	(a) Machine grooves in contact face of brake drum.	(a) Sand, reface or replace brake drum.

SERVICE DIAGNOSIS

Condition	Possible Cause	Correction
	(b) Weak hold down springs.	(b) Replace hold down springs.
BRAKES DO NOT SELF ADJUST	(a) Adjuster screw frozen in thread.	(a) Clean and free-up all thread areas.
	(b) Adjuster screw corroded at thrust washer.	(b) Clean threads and replace thrust washer if necessary.
	(c) Adjuster lever does not engage star wheel.	(c) Repair, free up or replace adjuster as required.
	(d) Adjuster installed on wrong wheel.	(d) Install correct adjuster parts.

SERVICE PROCEDURES

The eleven inch brakes used on taxi vehicles, (Fig. 4) are equipped with manual adjusters. The service procedures covering these brakes are identical to the passenger car, with the exception of reference to application adjusters. Illustrations of the various service procedures will not always show any one specific brake.

BRAKE DRUM REMOVAL

Removing Front Brake Drums

To aid in brake drum removal loosen brake star adjusting wheel.

(1) Remove rear plug from brake adjusting access hole.

(2) Insert a thin screwdriver into brake adjusting hole and push adjusting lever away from star adjusting wheel. **Care should be taken not to bend adjusting lever.**

(3) Insert Tool C-3784 into brake adjusting hole and engage notches of brake adjusting star wheel. Release brake adjustment by prying down with adjusting tool.

(4) Remove wheel cover, grease cap, cotter pin, lock, adjusting nut, outer wheel bearing and remove wheel and drum assembly from spindle to expose brake linings (Figs. 1, 2, 3 or 4).

(5) Inspect brake lining for wear, shoe alignment,

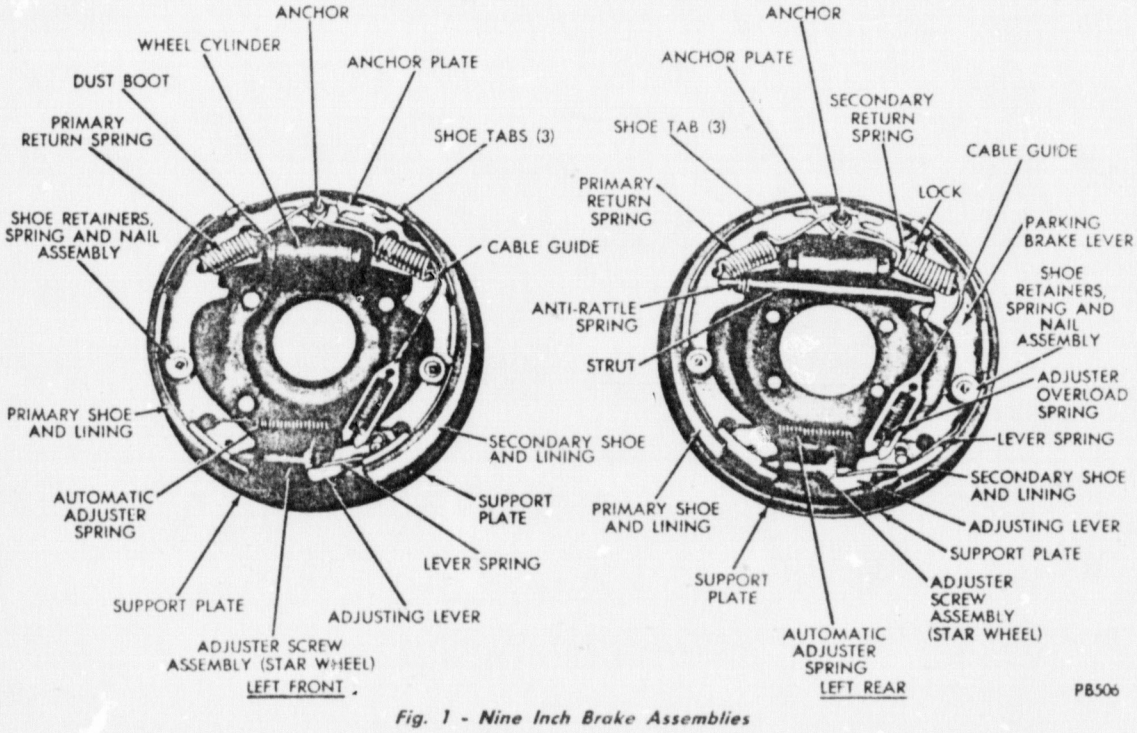

Fig. 1 - Nine Inch Brake Assemblies

5-8 DRUM BRAKES

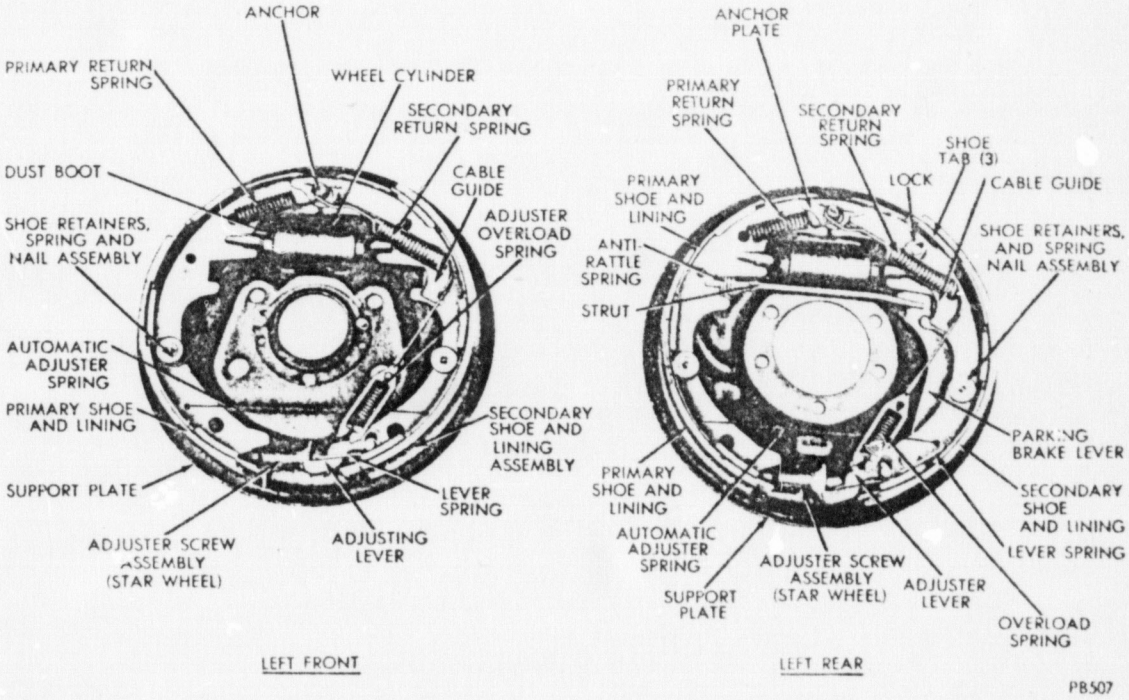

Fig. 2 - Ten Inch Brake Assemblies

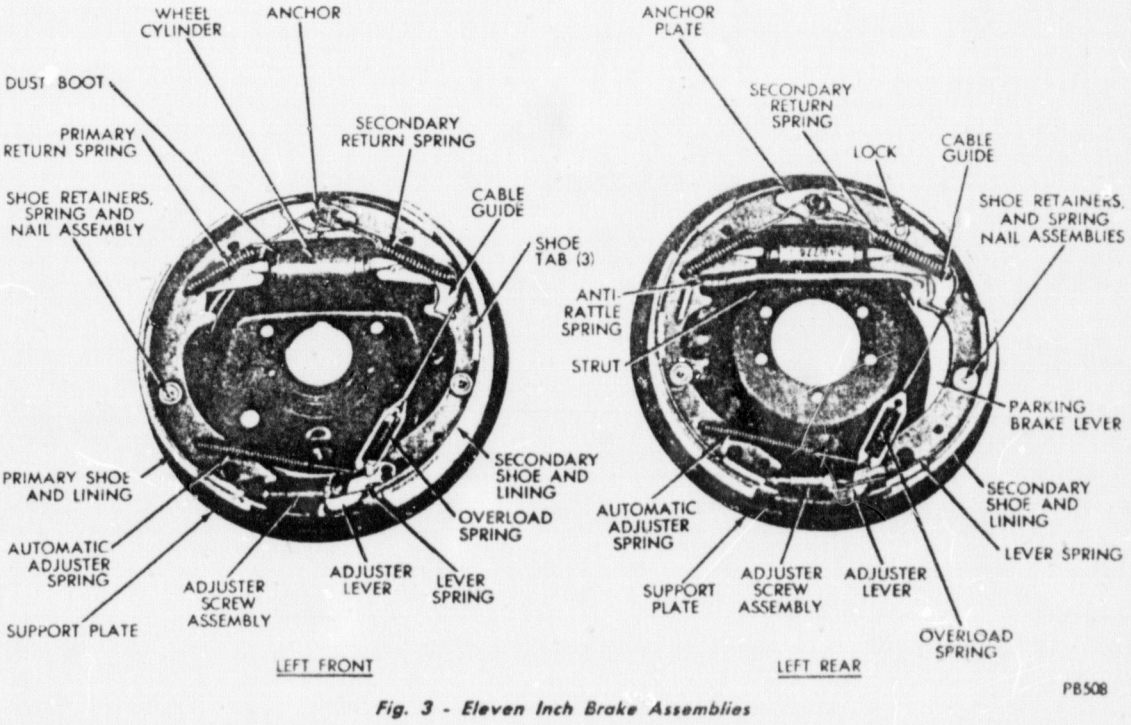

Fig. 3 - Eleven Inch Brake Assemblies

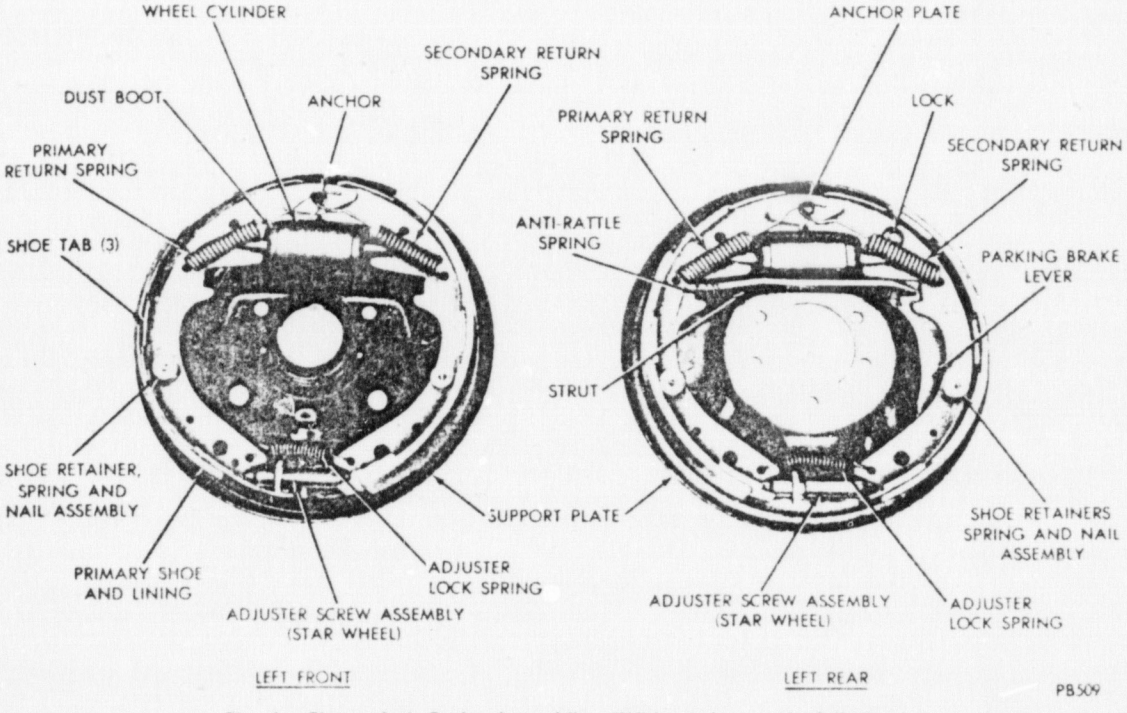

Fig. 4 - Eleven Inch Brake Assemblies (Without Automatic Adjusters)

or contamination from grease or brake fluid.

Removing Rear Brake Drums

(1) Remove rear plug from brake adjusting access hole.

(2) Insert a thin screwdriver into brake adjusting hole and hold adjusting lever away from notches of adjusting screw.

(3) Insert Tool C-3784 into brake adjusting hole and engage notches of brake adjusting screw. Release brake by prying down with adjusting tool.

(4) Remove rear wheel and clips from wheel studs that holds drum on axle. Discard clips. Remove drums.

(5) Inspect brake lining for wear, shoe alignment or contamination from grease or brake fluid.

BRAKE SHOE REMOVAL

Removing Front Brake Shoes

(1) Using Tool C-3785 remove brake shoe return springs (Fig. 5). (Note how secondary spring overlaps primary spring), (Fig. 1).

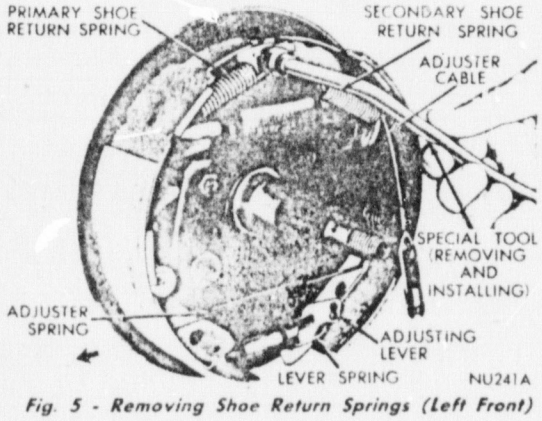

Fig. 5 - Removing Shoe Return Springs (Left Front)

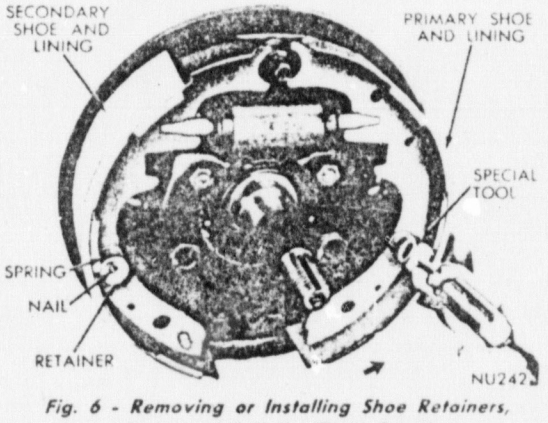

Fig. 6 - Removing or Installing Shoe Retainers, Springs and Nails (Right Front)

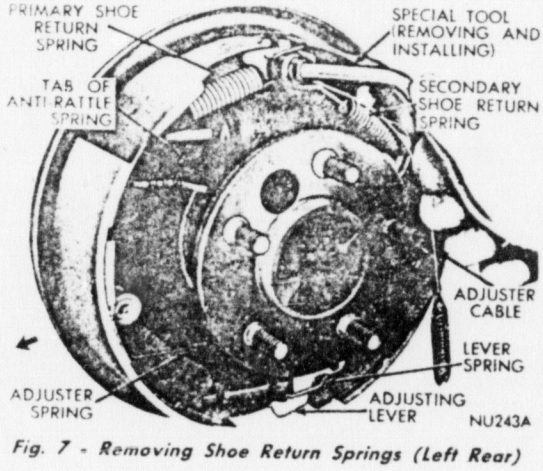

Fig. 7 - Removing Shoe Return Springs (Left Rear)

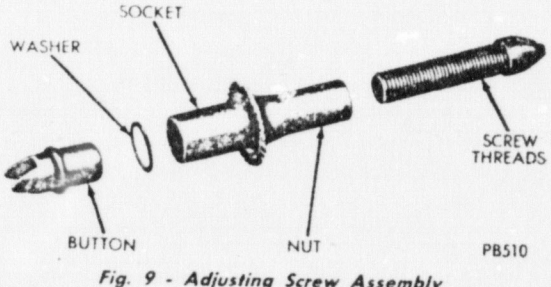

Fig. 9 - Adjusting Screw Assembly

(2) Slide eye of automatic adjuster cable off anchor and unhook from adjusting lever. Remove cable, overload spring, cable guide and anchor plate.

(3) Disengage adjusting lever from spring by sliding forward to clear pivot, then working out from under spring. Remove spring from pivot. Remove automatic adjuster spring from secondary shoe web and disengage from primary shoe web. Remove spring (Eleven inch brake only).

(4) Remove brake shoe retainers, springs and nails, using Tool C-4070, (Fig. 6).

(5) Disengage primary and secondary shoes from push rods (if so equipped) and remove from support. Remove adjusting star wheel assembly from shoes.

Removing Rear Brake Shoes

(1) Remove rear wheel, and drum retaining clips. Remove drum.

(2) Using Tool C-3785, remove brake shoe return springs (Fig. 7). (Note how secondary spring overlaps primary spring) (Fig. 1).

(3) Slide eye of automatic adjuster cable off anchor and then unhook from adjusting lever. Remove cable, overload spring, cable guide and anchor plate.

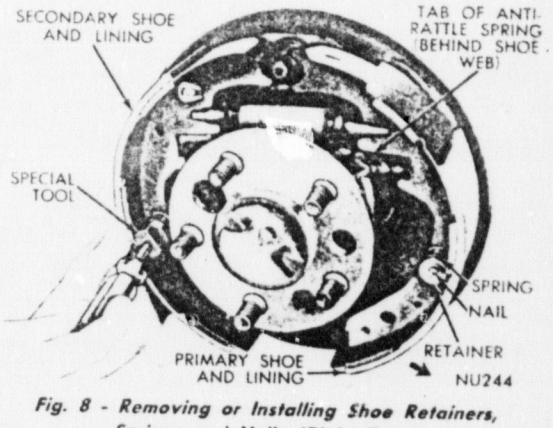

Fig. 8 - Removing or Installing Shoe Retainers, Springs and Nails (Right Rear)

(4) Disengage adjusting lever from spring by sliding forward to clear pivot, then working out from under spring. Remove spring from pivot. Remove automatic adjuster spring from secondary shoe web and disengage from primary shoe web. Remove spring (Eleven inch brake only).

(5) Disengage primary and secondary shoes from push rods (if so equipped) and remove adjusting star wheel assembly from shoes.

(6) Spread anchor ends of primary and secondary shoes and remove parking brake lever strut and anti-rattle spring (Fig. 12).

(7) Remove brake shoe retainers, springs and nails. Using Tool C-4070, (Fig. 8), and remove from support.

(8) Disengage parking brake cable from parking brake lever.

CLEANING AND INSPECTION

Wipe or brush clean (dry) the metal portions of the brake shoes. Examine the lining contact pattern to determine if the shoes are bent. The lining should show contact across the entire width, extending from heel to toe. Shoes showing contact only on one side should be replaced. Shoes having sufficient lining but lack of contact at toe and heel should be measured for proper grind.

Clean the support, using a suitable solvent, then inspect for burrs. Remove if necessary. Clean and inspect the adjusting screws for pulled or stripped threads, then apply a thin film of lubricant to the threads, socket and washer (Fig. 9).

New brake shoe return springs and hold down springs should be installed where the old springs have been subjected to overheating or if their strength is questionable. Spring paint discoloration or distorted end coils would indicate an overheated spring.

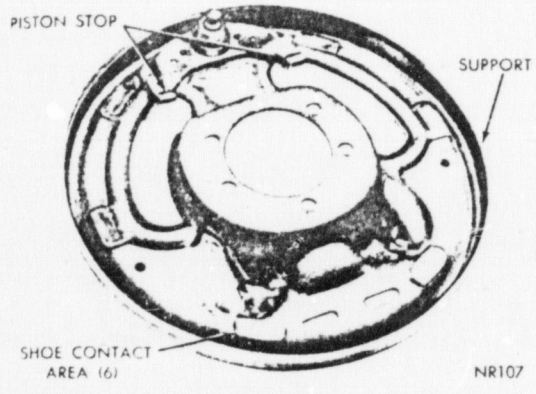

Fig. 10 - Shoe Contact Area on Support

GRINDING AND REFACING RECOMMENDATIONS

Brake Shoe Lining—New lining should be measured and ground .060 in. to .080 in. (maximum under the drum diameter). When replacing brake shoe and lining assemblies, always check them in the drum they are to be used with to insure that they have the recommended radius grind. This grind, which should provide at least .004 inch heel and toe clearance, is necessary for proper lining to drum contact during brake application.

Drum Refacing—Measure the drum runout and diameter with an accurate gauge. There should be no variation in the drum diameter greater than .002 inch. Drum runout should not exceed .006 inch out of round. If the drum runout or diameter variation exceed these values the drum should be refaced. Remove only as much material as is necessary to clean up the drum. It is recommended the front drums be refaced with the wheel and tire mounted. **Do not reface more than .060 inch over the standard drum diameter.**

NOTE: All drums will show markings of maximum allowable diameter. For example; a nine inch drum will have a marking of MAX. DIA. 9.090". This marking includes .030" for allowable drum wear beyond the recommended .060" of drum refacing.

BRAKE SHOE INSTALLATION

Installing Front Brake Shoes

Lubricate with a **thin film** the shoe tab contact area (6 places) on support plate with Chrysler support plate lubricant, Part number 2932524 or equivalent (Fig. 10).

(1) Match a primary with a secondary brake shoe and place them in their relative position on a work bench.

(2) Install adjusting star wheel assembly between primary and secondary shoes, with a star wheel next to secondary shoe (Fig. 1).

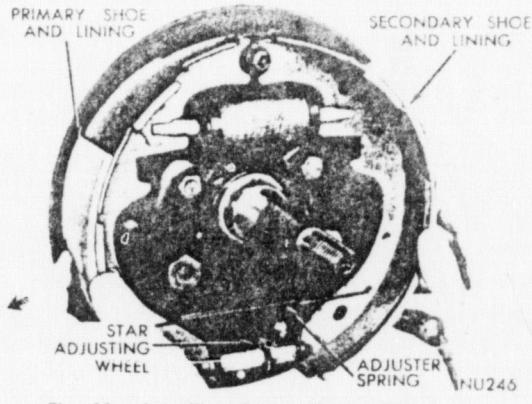

Fig. 11 - Installing Brake Shoes (Left Front)

The left star wheel adjusting stud end is stamped "L" (indicating its position on the vehicle) and is also cadium plated. The right star wheel is black, and the adjusting stud end is **not** stamped.

(3) Install adjuster spring in primary shoe and hook other end in web of secondary (Eleven inch brake only). Install adjusting lever spring over pivot pin on shoe web. Install adjusting lever under spring and over pivot pin. Slide lever slightly rearward to lock in position (Fig. 1).

(4) Spread anchor ends of brake shoe to hold star adjusting wheel assembly in position.

(5) Holding brake shoes firmly, place assembly on support plate, and at the same time engage shoe webs with push rods (If so equipped) (Fig. 11).

(6) Using Tool C-4070, install shoe retaining nails, springs and retainers. (Fig. 6).

(7) Install anchor plate over anchor.

(8) Slide "eye" of adjusting cable over anchor and against anchor plate. Engage end of primary shoe return spring in shoe web and install other end over anchor, using Tool C-3785.

(9) Install cable guide in secondary shoe web. Holding in position, engage secondary shoe return spring through guide and into web. Install other end over anchor, using Tool C-3785. (Be sure cable guide rests flat against shoe web, and that secondary spring overlaps primary) (Fig. 1). Using pliers, squeeze ends of spring loops (around anchor) until parallel.

(10) Thread adjuster cable over guide and hook end of overload spring in lever (Fig. 1). (Be sure "eye" of cable is pulled tight against anchor and in a straight line with guide).

Installing Rear Brake Shoes

Lubricate with a **thin film** the shoe tab contact area (6 places) on support plate with Chrysler Support plate lubricant, Part number 2932524 or equivalent (Fig. 10).

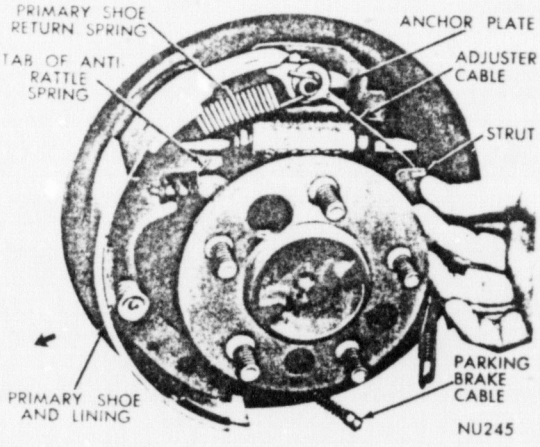

Fig. 12 - Removing or Installing Parking Brake Strut and Spring (Left Rear)

(1) Install parking brake lever on inner side of secondary shoe web after lubricating pivot with support plate lubricant. Secure with wave washer and horseshoe clip.

(2) Engage parking brake lever with cable, then slide secondary shoe against support plate, and at the same time engage shoe web with push rod, (if so equipped) and against anchor.

(3) Slide parking brake strut behind hub and into slot in parking brake lever. Slide anti-rattle spring over free end of strut (Fig. 12). On ten inch brakes, be sure spring tab is pointing rearward and up on outside of shoe web (Left Brake), and pointing frontward and down behind shoe web (Right Brake) (Fig. 12). On eleven inch brakes, be sure spring tab is pointing forward, down and inside of shoe web (both Left and Right Brake) (Fig. 3).

(4) Slide primary shoe into position and engage with push rod (if so equipped) and free end of strut. Install anchor plate over anchor, then install eye of adjuster cable over anchor (Fig. 13).

(5) Engage primary shoe return spring in web of shoe and install free end over anchor, using Tool C-3785. (Fig. 7).

(6) Install cable guide in secondary shoe web. Holding in position, engage secondary shoe return spring through guide and into web. Install other end over anchor, using Tool C-3785. (Be sure cable guide remains flat against shoe web and that secondary spring overlaps primary) (Fig. 1). Using pliers, squeeze ends of spring loops (around anchor) until parallel.

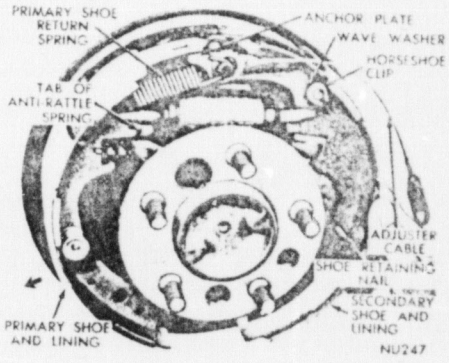

Fig. 13 - Installing Brake Shoes (Left Rear)

(7) Install adjusting star wheel assembly between primary and secondary shoes, with star wheel next to secondary shoe (Fig. 1). The left star wheel adjusting stud end is stamped "L" (indicating its position on the vehicle) and is also cadium plated. The right star wheel is black, and the adjusting stud end is **not** stamped. Install adjuster spring between shoes (Fig. 1). (Engage primary shoe first). (Eleven inch brake only).

(8) Install adjusting lever spring over pivot pin on shoe web. Install adjusting lever under spring and over pivot pin. Slide lever slightly rearward to lock in position.

(9) Using Tool C-4070, install shoe retaining nails, retainers and springs (Fig. 8).

(10) Thread adjuster cable over guide and hook end of overload spring in lever (Fig. 1). (Be sure eye of cable is pulled tight against anchor and in a straight line with guide).

BRAKE DRUM INSTALLATION

Installing Front Brake Drums

(1) Lubricate wheel bearings and install brake drum and adjust wheel bearing to proper preload.

(2) Adjust brakes as described under "Service Adjustments" at front of this Group.

Installing Rear Brake Drums

(1) Install brake drum. Reinstallation of retaining clips is not necessary. Install wheel and tire assembly.

(2) Adjust brakes as described under "Service Adjustments" at front of this Group.

MASTER CYLINDERS

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GENERAL INFORMATION

The tandem master cylinder (Fig. 1) is of the compensating ty[illegible] with the reservoirs cast integrally.

The **front** outlet tube from the master cylinder is connected to the hydraulic system warning switch and then to the **rear** brakes. The **rear** outlet tube from the master cylinder is also connected to the warning switch and the **front** brakes. The master cylinder used on vehicles not equipped with power brake units is serviced in the same manner as the master cylinder with power brakes, with one exception, the master cylinder for power brakes does not include the push rod.

The [illegible]c brake master cylinder is different than the [illegible]m brake master cylinder in reservoir, cover, bail, and gasket size, and only has one residual pressure valve (Fig. 1).

SERVICE PROCEDURES

MASTER CYLINDER REMOVAL

(1) Disconnect front and rear brake tubes from master cylinder (residual pressure valves will keep cylinder from draining the drum brake Master Cylinder). Install a plug in the rear outlet of the disc brake Master Cylinder.

(2) Remove nuts that attach master cylinder to cowl panel and/or power brake unit (if so equipped).

(3) Disconnect pedal push rod (manual brakes) from brake pedal.

(4) Slide master cylinder straight out from cowl panel and/or power brake unit (if so equipped).

DISASSEMBLING MASTER CYLINDER

To disassemble the master cycinder, (Fig. 1) clean outside of master cylinder thoroughly.

(1) Press bail to one side, remove cover and gasket. Empty brake fluid from reservoirs.

(2) Remove secondary piston retainer screw from inside reservoir, then remove snap ring from outer end of cylinder bore (Fig. 2). Slide primary piston assembly out of cylinder bore.

(3) Tamp open end of master cylinder on bench to remove secondary piston. If secondary piston sticks in bore of cylinder, use air pressure to force piston out of cylinder. **New cups must be installed at reassembly if air pressure is used.**

(4) Remove secondary piston compression spring from bore.

(5) Remove rubber cups from pistons, after noting positions of cup lips.

Do not remove the primary cup of the primary piston. If cup is damaged or worn, install a new primary piston assembly.

(6) Using Tool T109-178 (or an easy out) remove tube seats by threading tool firmly into seat, tap tool and seat out of cylinder body (Fig. 3).

(7) Remove two residual pressure valves and springs (Fig. 4).

CLEANING AND INSPECTION

Clean master cylinder thoroughly, using a suitable solvent and dry with compressed air. Wash the cylinder bore with clean brake fluid and inspect for scoring or pitting. Master cylinder bore walls that have light scratches or show signs of corrosion, can usually be cleaned with crocus cloth. However, cylinder bores that have deep scratches or scoring may be honed, providing diameter of bore is not increased more than .002 inch. If master cylinder bore does not clean up at .002 inch when honed, the master cylinder should be discarded and a new master cylinder installed.

If master cylinder pistons are badly scored or corroded, replace them with new ones. The piston cups and seals should be replaced when recondition-

5-14 MASTER CYLINDERS

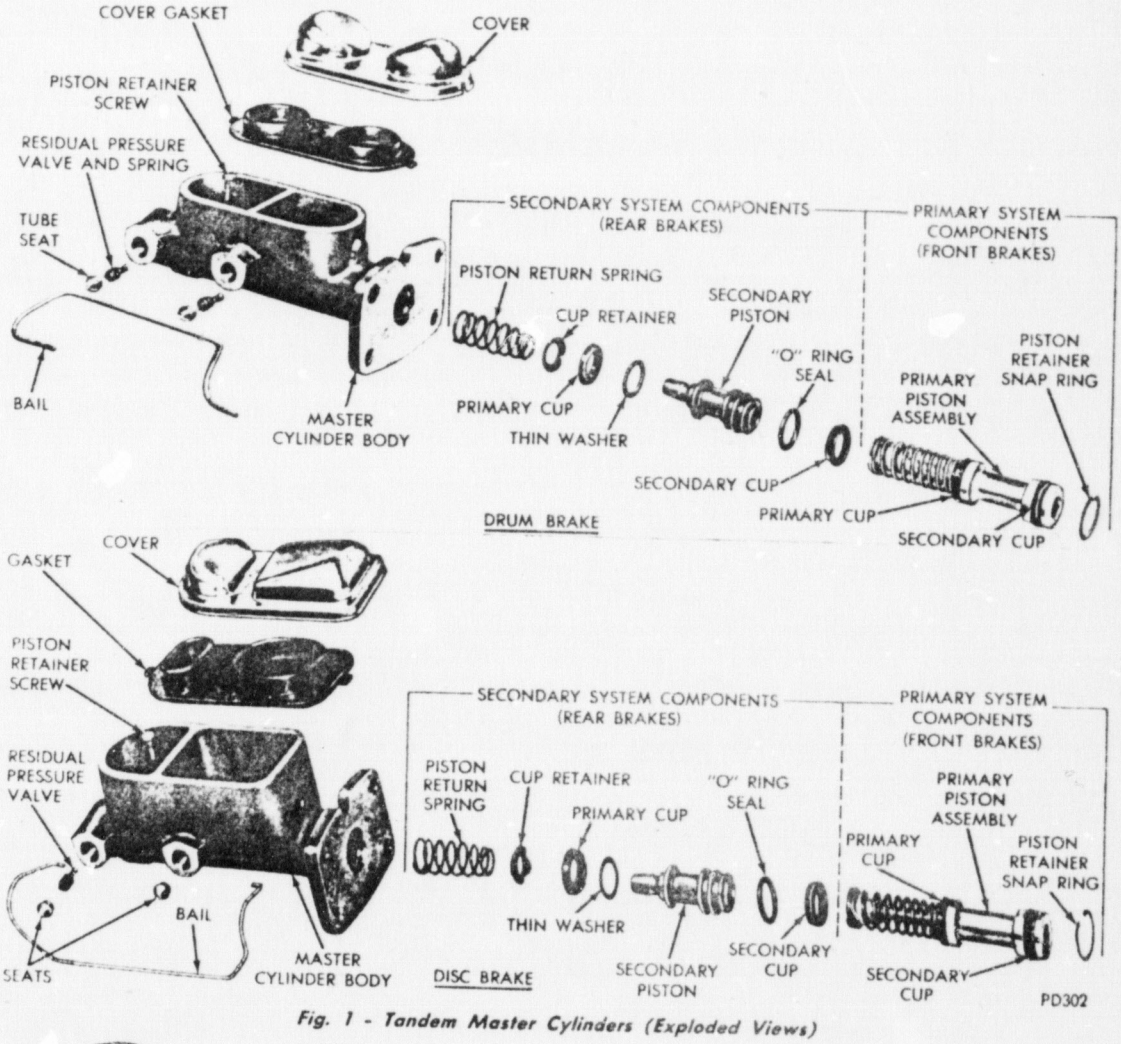

Fig. 1 - Tandem Master Cylinders (Exploded Views)

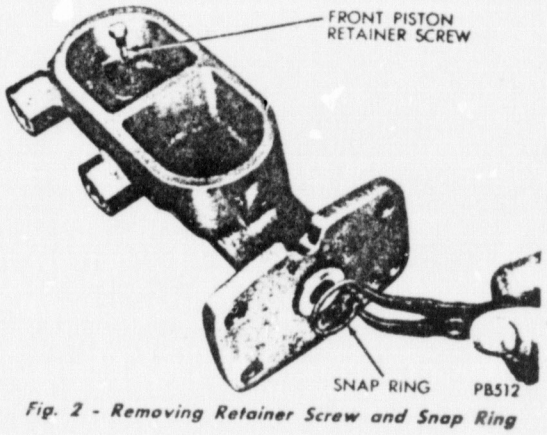

Fig. 2 - Removing Retainer Screw and Snap Ring

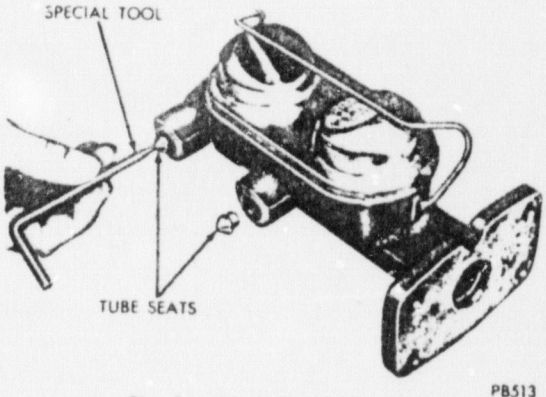

Fig. 3 - Removing Tube Seats

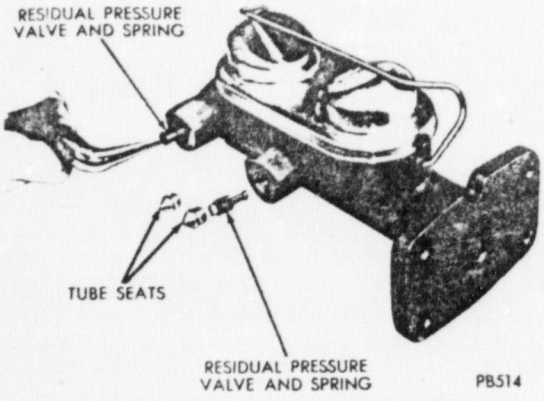

Fig. 4 - Removing or Installing Residual Pressure Valve

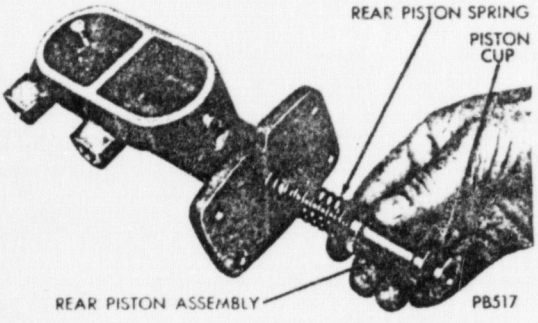

Fig. 6 - Installing Primary (Rear) Piston Assembly

ing a master cylinder.

When overhauling a master cylinder, use all parts furnished in repair kit. **Discard all used rubber parts.**

REASSEMBLING MASTER CYLINDER

Secondary (Front) Piston

Before assembling the master cylinder, dip all component parts in clean brake fluid and place on a clean shop towel or paper (assembling seals dry, can ruin them).

(1) Carefully work primary cup on end of secondary piston with the lip away from piston (Fig. 1).

(2) Slide "O" ring over the rear end of secondary piston and into correct land.

(3) Carefully work secondary piston secondary cup (Fig. 1) into rear land, with the cup lip away from piston.

(4) Slide cup retainer over front end of piston, followed by piston spring (Fig. 1).

(5) Install piston spring, piston cup retainer, piston and cups into bore of master cylinder (Fig. 5).

Be sure the lip of cups enter bore evenly in order not to damage sealing qualities of cups. (Keep well lubricated with brake fluid.)

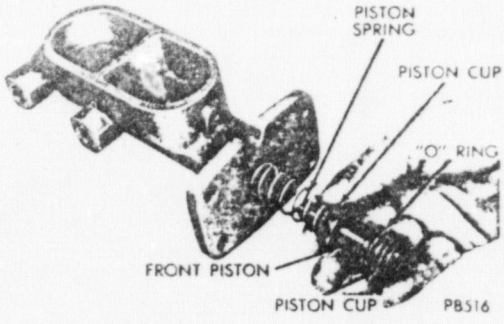

Fig. 5 - Installing Secondary (Front) Piston and Spring.

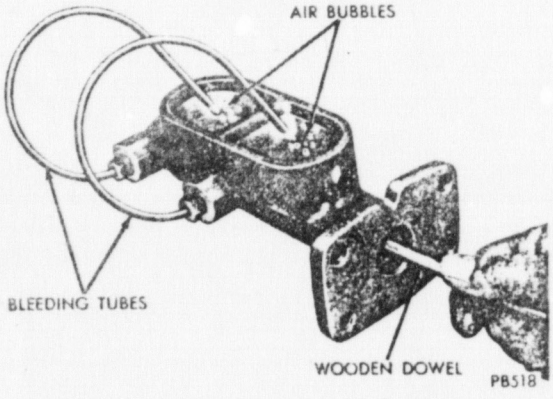

Fig. 7 - Bleeding Master Cylinder

Primary (Rear) Piston

(1) Carefully work secondary cup over rear end of primary piston with lip of cup toward piston (Fig 1).

(2) Center spring retainer of primary piston assembly over shoulder of secondary piston. Push piston assemblies into bore up to center piston cup. Carefully work cup into bore then push piston in up to the secondary cup. Carefully work lip of primary cup into bore, then push in on piston until seated (Fig. 6).

(3) Holding piston in seated position, install snapring (Fig. 2).

(4) Install secondary piston retaining set screw in reservoir and tighten securely (Fig. 2).

(5) Install residual pressure valves and springs in outlet ports and install tube seats, firmly.

BLEEDING MASTER CYLINDER

Before installing the master cylinder on vehicle, it must be bled on the bench as follows:

(1) Clamp master cylinder in a vise and attach bleeding tubes Tool C-4029 (Fig. 7).

(2) Fill both reservoirs with approved brake fluid.

(3) Using a wooden stick or dowel (power brake

equipped vehicles) or depress push rod slowly and allow the pistons to return under pressure of springs. Do this several times until all air bubbles are expelled (Fig. 7).

(4) Remove bleeding tubes from cylinder and install cover and gasket. (As tubes are removed, fluid remaining in tubes will syphon out.)

(5) Remove from vise and install master cylinder on vehicle as follows:

INSTALLING MASTER CYLINDER

(1) Install master cylinder on vehicle, aligning push rod with cowl panel opening (manual brakes) or power brake push rod with cylinder piston.

(2) Slide over mounting studs. Install attaching nuts and tighten 200 inch pounds. Connect push rod to brake pedal.

(3) Connect front and rear brake tubes and tighten to 150 inch-pounds.

(4) Bleed brakes at wheel cylinders using regular procedure, being sure fluid level is maintained. (See Bleeding the Brake System in "Service Adjustments").

TESTING MASTER CYLINDER

Be sure that the master cylinder compensates at both ports. This can be done by applying the pedal lightly with the engine running (power brakes) and observing for a gyser of fluid squirting up in the reservoirs. This may only occur in the front chamber and so to determine if the rear compensating port is open, it will be necessary to pump up the brakes rapidly and, then, hold the pedal down. Have an observer watch the fluid in the rear reservoir while the pedal is raised. A disturbance in the fluid indicates that the compensating port is open.

HYDRAULIC SYSTEM CONTROL VALVES

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GENERAL INFORMATION

All vehicles have some type of hydraulic system control valve or switch in the brake system. The valve is usually located under the master cylinder attached to the fender splash shield or frame rail.

All drum brake vehicles use a simple BRAKE (DIFFERENTIAL) WARNING SWITCH.

Disc brake vehicles use valves which combine the warning switch with a metering valve, a proportioning valve or both. (See application chart).

There is only **one valve or switch** in each vehicle.

VALVE APPLICATION CHART

Car Line	Brake Type	Hydraulic Valve Type	Assembly Number
Valiant	Drum	Brake Warning Switch	2925882 (Brass)
	Disc	Combination Brake Warning/ Proportioning	3466793 (Brass)
Barracuda	Drum	Brake Warning Switch	3583601 (Brass)
Satellite (Except Suburban)	Disc	Combination Brake Warning/ Proportioning/Metering	3583607 (Cast Iron)
Satellite Suburbans	Drum	Brake Warning Switch	3583609 (Brass)
	Disc	Combination Brake Warning/ Metering	3583608 (Cast Iron)
Fury Chrysler (Except Suburban)	Drum	Brake Warning Switch	2466792 (Brass)
	Disc	Combination Brake Warning/ Proportioning/Metering	3583635 (Cast Iron)
Fury Chrysler Suburban	Drum	Brake Warning Switch	3466792 (Brass)
	Disc	Combination Brake Warning/ Metering	3466781 (Cast Iron)
Imperial (Includes with Sure Brake)	Disc	Combination Brake Warning/ Proportioning/Metering	3583635 (Cast Iron)

SERVICE PROCEDURES

BRAKE WARNING SWITCH (DRUM BRAKES)

The hydraulic system brake warning switch (Figs. 1 and 2) is used to warn the vehicle operator that one of the hydraulic systems has failed. A failure in one part of the brake system does not result in failure of the entire hydraulic brake system. As an example, failure of the rear brake system will leave the front brake system still operative.

As pressure falls in one system, the other system's normal pressure forces the piston to the inoperative side contacting the switch terminal, causing a red warning light to come on in the instrument panel, thus, warning the operator of the vehicle that one of the systems has failed and should be repaired.

The safety switch is mounted on the frame in a vertical position, with the brake tubes connected (Fig. 9).

If a malfunction occurs within the switch, disconnect tubes from body assembly and install a new assembly. **The component parts of the switch body are not serviced.** However, the terminal unit can be removed if a malfunction occurs and a new terminal unit installed.

If a new body is installed, bleed the brake system.

TESTING BRAKE WARNING SWITCH

The brake warning light flashes only when the parking brake is applied with the ignition key turned "ON". The same light will also illuminate should one of the two service brake systems fail when the brake pedal is applied. To test the system turn the ignition key "ON", and apply the parking brake. If the light fails to light, inspect for a burned out bulb, disconnected socket, a broken or disconnected wire at the switch.

To test the service brake warning system, raise the car on a hoist and open a wheel cylinder bleeder while a helper depresses the brake pedal and observes the warning light. If the light fails to light, inspect for a burned out bulb, disconnected socket, a broken or disconnected wire at the switch. If the bulb is not burned out and the wire continuity is proven, replace the brake warning switch in the brake line Tee fitting mounted on the frame rail in the engine compartment below the master cylinder.

COMBINATION BRAKE WARNING SWITCH/PROPORTIONING VALVE

This valve combines the brake (differential) warning switch and the rear brake proportioning valve into one body, and in addition incorporates a proportioning valve bypass feature which provides full pressure to the rear brakes in the event of front system pressure loss.

BRAKE WARNING SWITCH UNIT

The brake warning switch unit of the brake warning switch/proportioning valve assembly (Fig. 3) is used to warn the vehicle operator that one of the hydraulic systems have failed. A failure in one part of the brake system does not result in failure of the entire hydraulic brake system. As an example, failure of the rear brake system will leave the front brake system still operative.

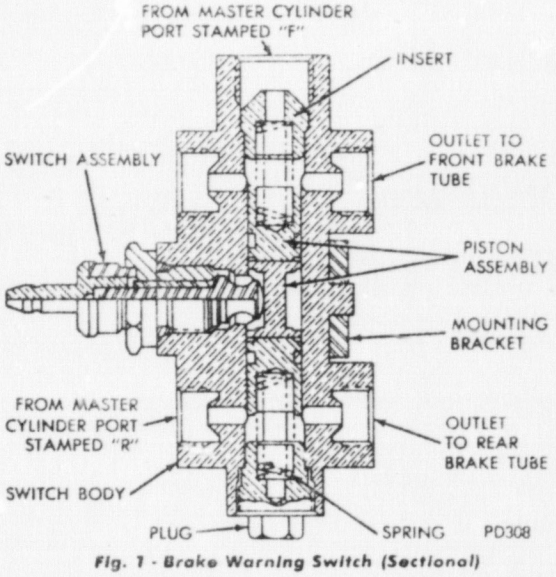

Fig. 1 - Brake Warning Switch (Sectional)

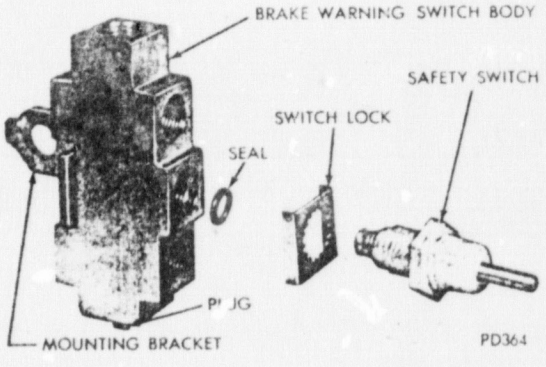

Fig. 2 - Brake Warning Switch (Exploded View) Typical

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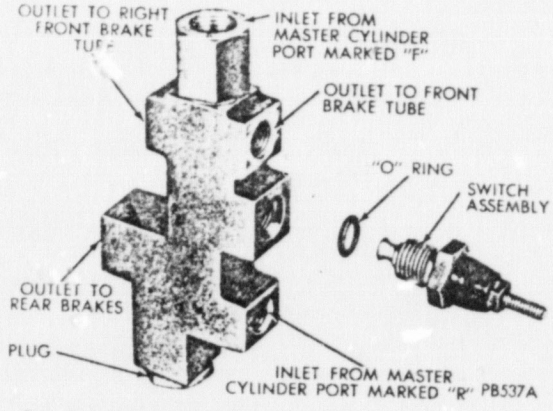

Fig. 3 - Brake Warning Switch/Proportioning Valve Assembly (Exploded View)

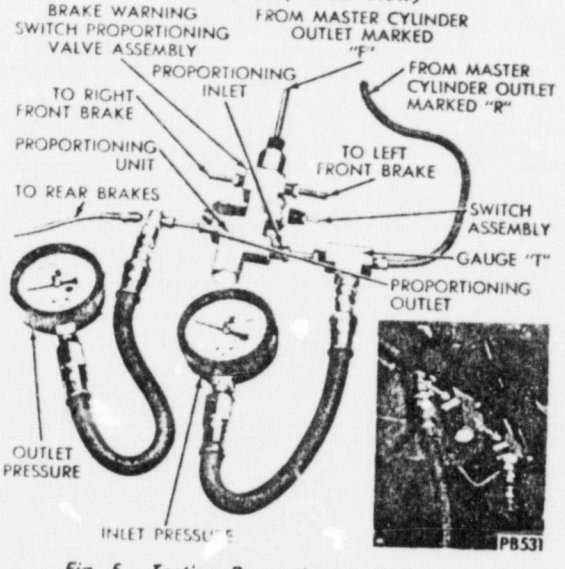

Fig. 5 - Testing Proportioning Valve Unit

As pressure falls in one system, the other system's normal pressure forces the piston to the inoperative side, contacting the switch terminal, causing a red warning light to come on in the instrument panel, thus warning the operator of the vehicle, that one of the systems has failed and should be repaired.

If a malfunction occurs within the switch, disconnect tubes from body assembly and install a new assembly. **The component parts of the switch body are not serviced.** However, the terminal unit can be removed if a malfunction occurs, and a new terminal unit installed.

If a new warning switch body assembly is installed, bleed the brake system.

TESTING BRAKE WARNING SWITCH UNIT

The testing procedure for the warning switch unit of the brake warning switch/proportioning valve assembly is identical to that used for the drum brake warning switch.

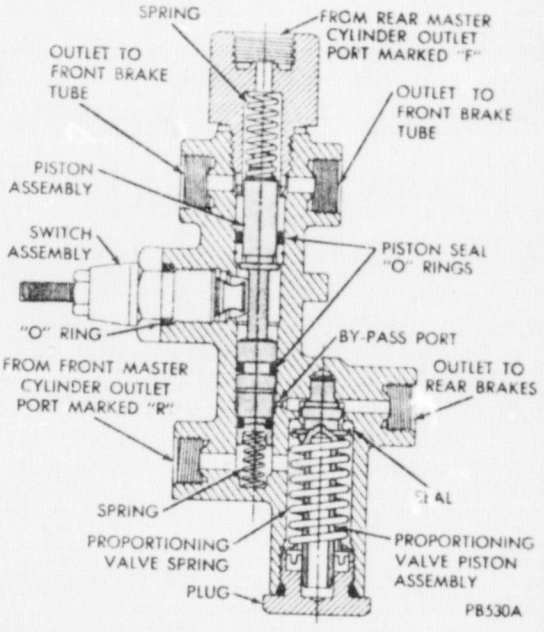

Fig. 4 - Brake Warning Switch/Proportioning Valve Assembly (Sectional)

PROPORTIONING VALVE UNIT

The proportioning valve unit of the brake warning switch/proportioning valve assembly (Figs. 3 and 4) operates by restricting, at a given ratio, hydraulic pressure to the rear brakes when system hydraulic pressure reaches a certain point.

On light pedal application the valve allows full brake hydraulic pressure to the rear brakes.

If hydraulic pressure is lost in the front brake system, rear brake system hydraulic pressure moves the brake warning switch piston and opens a bypass in the proportioning unit allowing full rear brake hydraulic pressure.

TESTING PROPORTIONING VALVE UNIT

When a premature rear wheel slide is obtained on brake application, it usually is an indication that the fluid pressure to the rear brakes is above the reduction ratio for the rear line pressure and that a malfunction has occured within the proportioning valve, which should be tested.

To test the proportioning valve, proceed as follows:

(1) Install one of gauge set C-4007A and "T" between brake line from master cylinder port marked "R" and brake warning switch/proportioning valve assembly, and remaining gauge between output end of valve unit and rear brake line (Fig. 5). Be sure front brake tubes remain connected when testing the

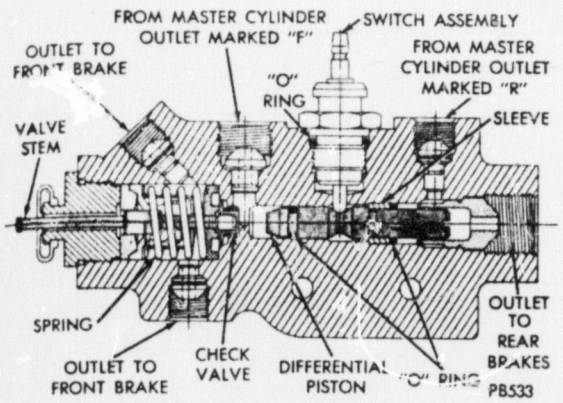

Fig. 6 - Brake Warning Switch/Metering Valve Assembly (Sectional)

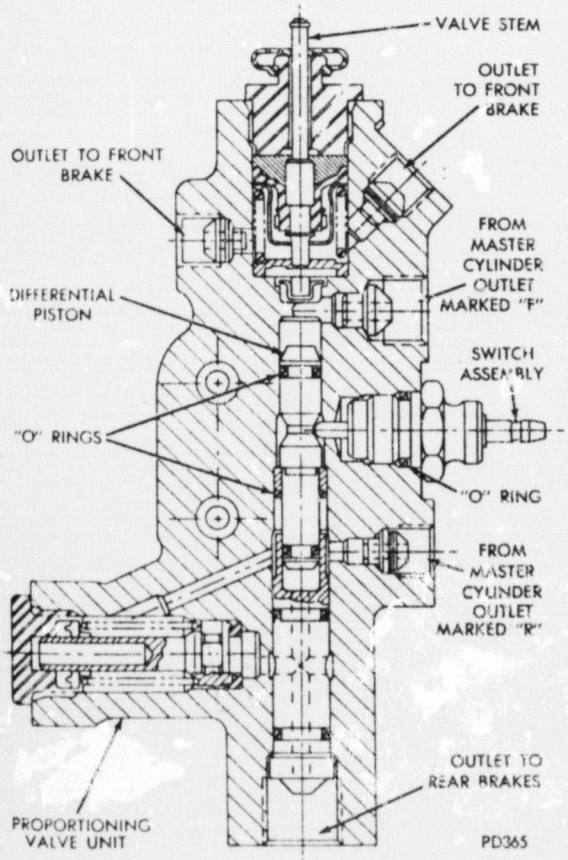

Fig. 8 - Combination Brake Warning/Proportioning /Metering Valve Assembly (Sectional)

proportioning valve and be sure all joints are fluid tight.

(2) Have a helper exert pressure on brake pedal (holding pressure). Obtain a reading on master cylinder output of approximately 500 p.s.i.

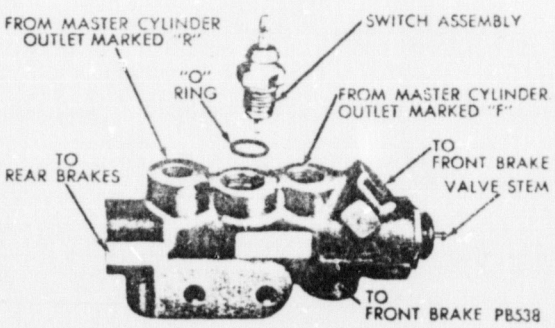

Fig. 7 - Brake Warning Switch/Metering Valve Assembly (Exploded)

(3) While pressure is being held as above, reading on valve outlet Gauge should be 360 to 405 p.s.i.

If the proportioning valve pressure readings do not meet the specifications, the assembly should be replaced.

COMBINATION BRAKE WARNING SWITCH/METERING VALVE

All disc brake equipped suburbans use a brake warning switch and metering valve combined into one body (Fig. 6 and 7).

METERING VALVE UNIT OPERATION

The metering valve holds off hydraulic pressure to the front disc brakes in the 35 to 135 psi range to allow the rear drum brake shoes to overcome the return springs and begin to contact the drums. This feature helps prevent locking the front brakes on icy surfaces under light braking conditions. The metering valve has no effect on front brake pressure during hard stops.

CHECKING METERING VALVE

(1) A slight "bump" can be felt by the foot as the brake pedal is stroked. This bump will occur after the pedal has been stroked about 1 inch.

(2) A visual check will show that the valve stem extends slightly when the brakes are applied and retracts when the brakes are released.

(3) In case of a metering valve malfunction, remove valve and install a new combination valve assembly.

BRAKE WARNING SWITCH UNIT (COMBINATION BRAKE WARNING SWITCH/METERING VALVE)

The brake warning switch used in these combination valves are one of two latching types. If a pressure loss occurs in one side of the dual brake system the piston in the valve will move toward the failed side and latch in that position. This will cause the brake system warning light to come on and stay on until the brake system is repaired. After repairing and bleeding the brake system, applying the brakes with moderate force will hydraulically re-center the piston and automatically turn off the warning light. **DO NOT DISASSEMBLE THE VALVE TO RESET THE PISTON.**

5-20 HYDRAULIC SYSTEM CONTROL VALVES

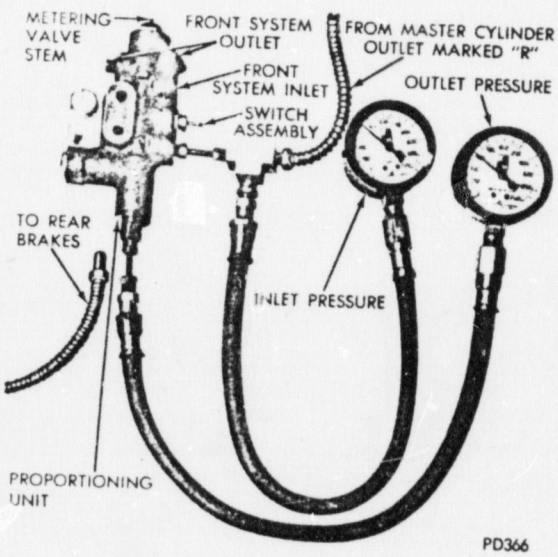

Fig. 9 - Testing Proportioning Unit of Combination Brake Warning/Froportioning/Metering Valve

TESTING BRAKE WARNING SWITCH UNIT

The brake warning light flashes only when the parking brake is applied with the ignition key turned "ON". The same light will also illuminate should one of the two service brake systems fail.

To test the system turn the ignition key "ON", and apply the parking brake. If the light fails to light, inspect for a burned out bulb, disconnect socket, a broken or disconnected wire at the switch.

To test the service brake warning system, raise the car on a hoist and open a wheel cylinder bleeder while a helper depresses the brake pedal and observes the warning light. If the light fails to light, inspect for a burned out bulb, disconnected socket, a broken or disconnected wire at the switch. If the bulb is not burned out and the wire continuity is proven, replace the brake warning switch mounted in the engine compartment below the master cylinder.

COMBINATION BRAKE WARNING SWITCH/METERING/PROPORTIONING VALVE (ALL DISC BRAKE EXCEPT VALIANT AND SUBURBAN MODELS)

The "3-way" combination valve (Fig. 8) contains the same metering and brake warning switch units as the combination brake warning switch/metering valve. In addition this valve contains a rear brake proportioning valve bypass feature.

PROPORTIONING VALVE UNIT

The proportioning valve unit operates by restricting, at a given ratio, hydraulic pressure to the rear brakes when system hydraulic pressure reaches a certain point.

On light pedal application the valve allows full brake hydraulic pressure to the rear brakes.

If hydraulic pressure is lost in the front brake system, rear brake system hydraulic pressure moves the brake warning switch piston and open and by-pass in the proportioning unit allowing full rear brake hydraulic pressure.

TESTING PROPORTIONING VALVE UNIT

When a premature rear wheel slide is obtained on brake application, it usually is an indication that the fluid pressure to the rear brakes is above the 50% reduction ratio for the rear line pressure and that a malfunction has occurred within the proportioning valve unit which should be tested.

To test the proportioning valve, proceed as follows:

NOTE: During testing leave front brake lines connected to the valve.

(1) Install one gauge and "T" of set C-4007A between brake line from master cylinder port marked "R" and brake valve assembly (Fig. 9).

(2) Install the second gauge and "T" of set C-4007A between valve assembly and the rear brake line. (An adapter tube made up locally of a 9/16 x 20 tube nut short piece of brake tube and 3/8 x 24 tube nut will be required to connect the "T" to the valve).

(3) Have a helper exert pressure on the brake pedal (holding pressure) to get a reading on the valve inlet gauge and check the reading on the outlet gauge, if the inlet and outlet pressures do not agree with the values on the following chart. Replace the valve.

Model	Inlet Pressure From Master Cylinder	Outlet Pressure To Rear Brakes
Fury, Chrysler, Imperial	700	550-610
Valiant, Barracuda Satellite	500	360-405

(5) **New valve assemblies are shipped in the front failed position to improve bleeding.** When installing a new valve bleed the rear brakes first. After bleeding both front and rear systems applying the brakes with moderate force will hydraulically reset the switch and turn off the warning light.

BLEEDING VEHICLES WITH METERING VALVES (BOTH BRAKE WARNING SWITCH/METERING AND BRAKE WARNING SWITCH/METERING/ PROPORTIONING ASSEMBLIES)

All disc brake vehicles except Valiant models, are equipped with a pressure metering valve. The valve is located (in the combination valve) on the left

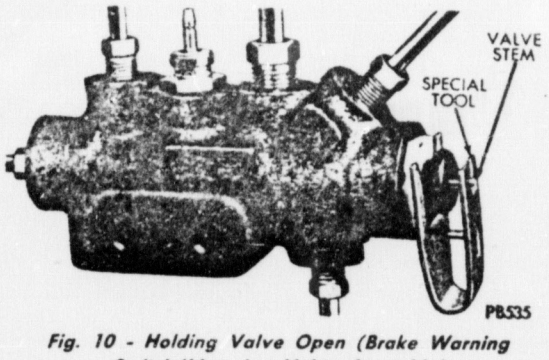

Fig. 10 - Holding Valve Open (Brake Warning Switch/Metering Valve Assembly)

frame rail. The use of the metering valve is to better match front disc brakes with the rear drum brakes, resulting in improved braking and steering control on icy surfaces.

Due to operating characteristics of the valve, which causes complete shut-off of the flow of brake fluid between approximately 3 and 135 psi, front brake bleeding procedures should be done as follows:

(1) **Gravity Bleed:** This method of bleeding is not effected by the metering valve, as fluid pressures are always below 3 psi. Remove master cylinder reservoir cover and gasket, then fill reservoirs with approved brake fluid. Open disc brake bleeder screws, and allow fluid and air to drain until stream of fluid is free of air.

(2) **Pedal Bleed:** This method of bleeding is not affected by the metering valve, as fluid pressures are in excess of 135 psi. Follow normal procedure of pumping pedal and opening bleeder screws. **Do not pump master cylinder dry!**

(3) **Pressure Bleed.** This method of bleeding is influenced by the metering valve. Bleed pressure, which is normally about 35 psi, is high enough to cause the metering valve to close, stopping the flow of fluid to the front brakes. However, the valve (Fig. 10) can be held open manually by using **Tool C-4121,** to pull the valve stem out.

CAUTION: Under no condition should a rigid clamp, wedge or block be used to depress the valve stem, as this can cause an internal failure in the valve, resulting in complete loss of front brakes.

It should be noted that the pressure release valve stem is in its innermost position when there is no pressure present. No attempt should be made to further depress the valve stem.

BLEEDING SATELLITE AND BARRACUDA MODELS WITH COMBINATION BRAKE WARNING SWITCH/METERING/PROPORTIONING VALVES

Because the valve assemblies in these models are mounted vertically the following bleeding procedure should be followed.

(1) Crack a front bleeder screw and apply the brakes to produce a front failure condition (the warning light will come on and stay on).

(2) Bleed the **rear** brakes using any of the three approved methods described above.

(3) Bleed the front brakes using any of the three approved methods (see "Bleeding Vehicles with Metering Valve").

(4) After bleeding both brake systems apply the brakes with moderate force. This will hydraulically recenter the brake warning switch and turn off the warning light.

WHEEL CYLINDERS

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GENERAL INFORMATION

A piston stop (Fig. 1) is welded to the support plates to prevent the pistons from moving out far enough to lose brake fluid. The piston boots are of the press-on type and prevents moisture from entering the wheel cylinder.

To perform service operations or inspections of the wheel cylinders, it will be necessary to remove the cylinders from the support plate and disassemble on the bench.

REMOVING WHEEL CYLINDERS

Front or Rear

With all the brake drums removed, inspect the wheel cylinder boots for evidence of a brake fluid leak. Visually check the boots for cuts, tears, or

5-22 WHEEL CYLINDERS

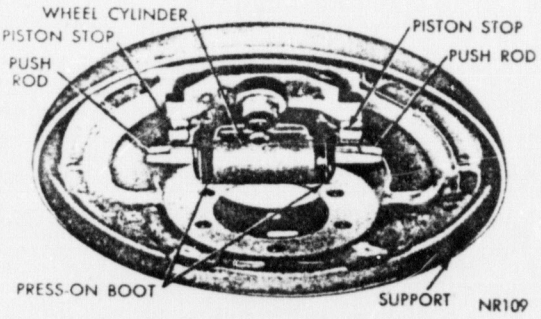

Fig. 1 - Wheel Cylinder Piston Stops

heat cracks, and if any of these conditions exist, the wheel cylinders should be completely cleaned, inspected and new parts installed. (A slight amount of fluid on the boot may not be a leak, but may be preservative fluid used at assembly.)

(1) In case of a leak, remove brake shoes, (replace if soaked with grease or brake fluid.)

(2) Disconnect brake hose from brake tube at frame bracket (front wheels) or disconnect brake tube from wheel cylinder (rear wheels).

(3) Disconnect brake hose or tube from wheel cylinder (front). Remove wheel cylinder attaching bolts (front or rear), then slide wheel cylinder assembly out of support.

DISASSEMBLING WHEEL CYLINDERS

Front or Rear

To disassemble the wheel cylinders, (Figs. 2 or 3) proceed as follows:

(1) Using a suitable tool, pry boots away from cylinders and remove. Remove push rods (if so equipped).

(2) Press in on one piston and force out piston, cup, spring cup and piston.

(3) Wash wheel cylinder, pistons, and spring in clean brake fluid or alcohol; clean thoroughly and blow dry with compressed air. Inspect cylinder bore and piston for scoring and pitting. (Do not use a rag as lint from the rag will adhere to bore surfaces.)

Wheel cylinder bores and pistons that are badly scored or pitted should be replaced. Cylinder walls that have light scratches, or show signs of corrosion, can usually be cleaned with crocus cloth, using a circular motion. Black stains on the cylinder walls are caused by piston cups and will not impair operation of cylinder.

ASSEMBLING WHEEL CYLINDERS

Front or Rear (Figs. 2 or 3)

Before assembling the pistons and new cups in the wheel cylinders, dip them in clean brake fluid. If the boots are deteriorated, cracked or do not fit tightly on the push rods or the cylinder casting, new boots must be installed.

(1) Coat cylinder bore with clean brake fluid.

(2) Install expansion spring in cylinder. Install cups in each end of cylinder with open end of cups facing each other.

(3) Install pistons in each end of cylinder with recessed end of pistons facing open ends of cylinder.

(4) Install boots over ends of cylinder and press over ends until boot is seated against cylinder shoulder. **Use care not to damage boot.**

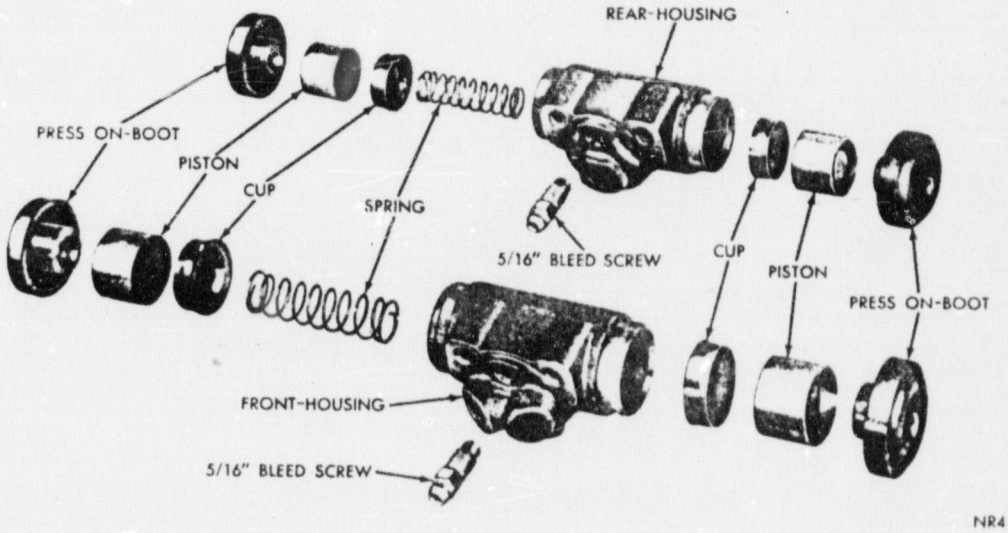

Fig. 2 - Wheel Cylinder 9 Inch Brake (Front & Rear)

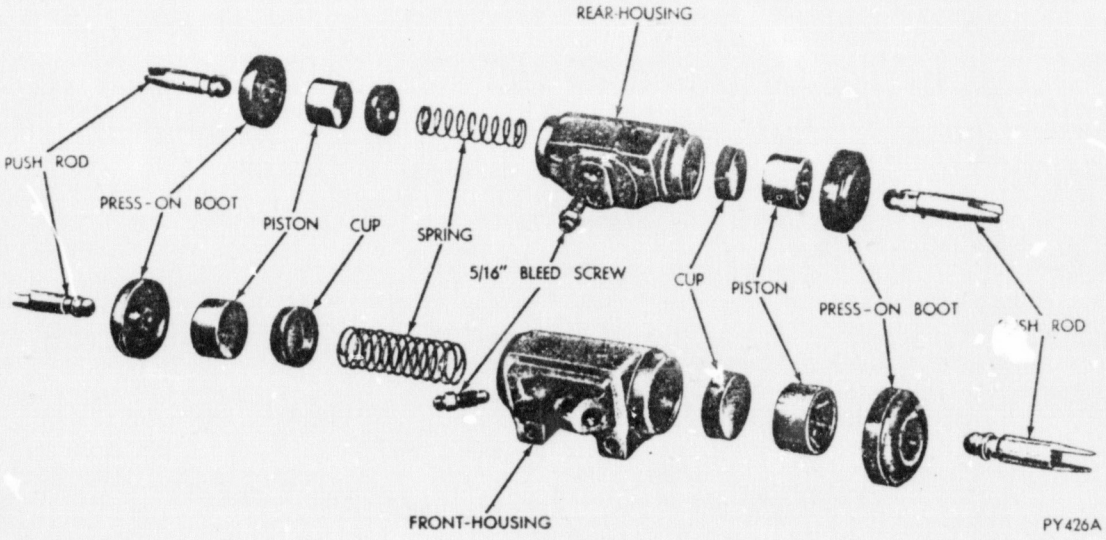

Fig. 3 - Wheel Cylinders 10 and 11 Inch Brake

INSTALLING WHEEL CYLINDERS

Front or Rear

(1) Slide wheel cylinder into position on support (front or rear). Install mounting screws and torque to 110 inch-pounds (9 inch brakes) or 220 inch-pounds (10 and 11 inch brakes). A small amount of rotation of the wheel cylinder may be expected.

(2) Connect brake tube to rear wheel cylinder and torque to 115 inch-pounds.

(3) **All except Valiant.** Connect brake hose to front wheel cylinder, using a new gasket. Torque to 25 foot-pounds, before attaching brake hose to frame bracket. Then attach brake hose to frame bracket.

CAUTION: The flexible hydraulic brake hose should always be installed in the vehicle by first tightening the male end of the hose in the wheel cylinder or rear axle housing tee. The hose should then be attached to the hose bracket in a manner to give minimum twist (15 degree twist is the maximum recommended). Excessive twist can result in hose interference problems with possible hydraulic system failure.

Valiant only. Connect jumper tube (Fig. 4) into wheel cylinder and torque to 115 inch-pounds. Attach brake hose to frame bracket and connect brake line to hose and torque to 115 inch-pounds. Position brake hose through stand off bracket and thread jumper tube into brake hose. Attach brake hose to stand off bracket and then torque jumper tube to 105 inch-pounds.

(4) Connect brake line to hose and torque to 115 inch-pounds.

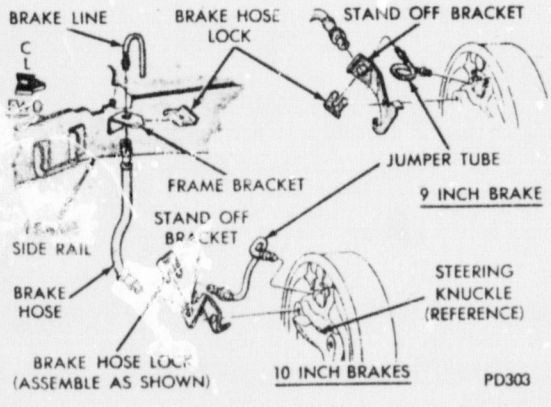

Fig. 4 - Wheel Cylinder to Brakeline Components

REMOVING BRAKE SUPPORT

(Front)

(1) Disconnect brake line from brake hose at frame bracket.

(2) With wheel and brake drum removed, remove four support attaching nuts and washers.

(3) Remove support and brake assembly from spindle.

(Rear)

(1) With wheel and brake drum removed, remove support attaching nuts and washers.

(2) Remove rear axle shaft and retainer.

(3) Disconnect hydraulic brake line from wheel cylinder.

(4) Disengage brake cable from parking brake

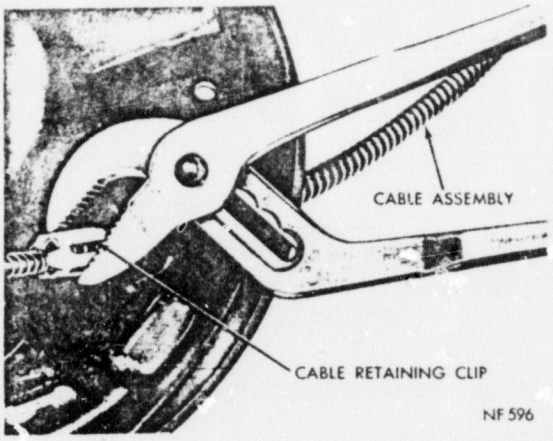

Fig. 5 - Removing Brake Cable From Support

lever.

(5) Using a suitable tool compress three flared legs of cable retainer and pull brake cable out of support (Fig. 5).

(6) Remove brake support from rear axle housing.

INSTALLING BRAKE SUPPORT

(Front)

(1) **All except Valiant**

Place support on spindle and install attaching bolts, nuts, and washers. Torque the top attaching bolts to 55 foot-pounds. The bottom attaching bolts are to be torqued to 120 foot-pounds.

(2) **Valiant only**

Place support on spindle and install attaching bolts, nuts, and washers. Torque the top attaching bolts to 55 foot-pounds. The bottom attaching bolts are to be torqued to 100 foot-pounds.

(3) Connect brake hose to wheel cylinder and tighten to 25 foot-pounds, before connecting brake hose to frame bracket. Then attach brake hose to frame bracket.

CAUTION: The flexible hydraulic brake hose should always be installed in the vehicle by first tightening the male end of the hose in the wheel cylinder or rear axle housing tee. The hose should then be attached to the hose bracket in a manner to give minimum twist (45 degree twist is the maximum recommended). Excessive twist can result in hose interference problems with possible hydraulic system failure.

(4) Connect brake line to brake hose and torque to 115 inch-pounds.

(Rear)

(1) Install brake shoes on support.

(2) Install support onto rear axle housing.

(3) Insert rear axle shaft and retainer into housing and install axle retainer nuts and washers. Tighten retainer nuts to 35 foot-pounds.

(4) Attach brake line to wheel cylinder and tighten to 115 inch-pounds.

(5) Insert parking brake cable into support plate and attach cable to parking brake lever.

(6) Install brake drum and wheel. Bleed and adjust brakes.

PARKING BRAKES

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GENERAL INFORMATION

The rear wheel service brakes also act as parking brakes. The brake shoes are mechanically operated by a lever and strut connected to a flexible steel cable. The wheel brake cables are joined together by a forward brake cable and equalizer extending to the parking brake pedal or release handle (Figs. 1, 2 and 3).

SERVICE DIAGNOSIS

Condition	Possible Cause	Correction
DRAGGING BRAKE	(a) Improper cable or brake shoe adjustment.	(a) Properly adjust the service brakes, then adjust the parking brake cable.
	(b) Broken brake shoe return spring.	(b) Replace any broken return spring.
	(c) Broken brake shoe retainer spring.	(c) Replace the broken retainer spring.
	(d) Grease or brake fluid soaked lining.	(d) Replace the grease seal or recondition the wheel cylinders and replace both brake shoes.
	(e) Improper stop light switch adjustment	(e) Adjust stop light switch
	(f) Sticking or frozen brake cable.	(f) Replace cable.
	(g) Broken rear spring.	(g) Replace the broken rear spring.
	(h) Bent or rusted cable equalizer.	(h) Straighten, or replace and lubricate the equalizer.
	(i) Heat set parking brake cable spring.	(i) Replace parking brake cable.
BRAKE WILL NOT HOLD	(a) Broken or rusted brake cable.	(a) Replace cable.
	(b) Improperly adjusted brake or cable.	(b) Adjust brakes and cable as necessary.
	(c) Soaked brake lining.	(c) Replace the brake lining.
	(d) Ratchet or pedal mechanism worn.	(d) Replace pedal assembly.

SERVICE PROCEDURES

ADJUSTING PARKING BRAKE

The service brakes must be properly adjusted before adjusting the parking brake.

(1) Release parking brake lever and loosen cable adjusting nut to insure cable is slack, (Figs. 1, 2 or 3). Before loosening cable adjusting nut, clean threads with wire brush and lubricate with grease.

(2) Tighten cable adjusting nut until a slight drag is felt while rotating wheel, loosen cable adjusting nut until both rear wheels can be rotated freely, then back off cable adjusting nut two full turns on all models.

(3) Apply parking brake several times, then release and test to see that rear wheels rotate freely without dragging.

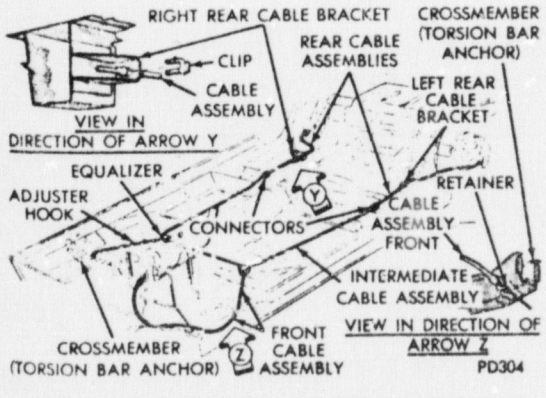

Fig. 1 - Parking Brake Cable Routing (Valiant)

REMOVING REAR PARKING BRAKE CABLE

The independent rear brake cables are attached to an equalizer (Figs. 1, 2 or 3). The front cable is adjusted at the equalizer.

Should it become necessary to remove the parking brake cable (rear) for installation of a new cable, proceed as follows.

(1) With vehicle jacked up or on a suitable hoist, remove rear wheels.

(2) Disconnect brake cable from equalizer.

(3) Remove retaining clip from brake cable bracket.

(4) Remove brake drum from rear axle.

(5) Remove brake shoe return springs.

(6) Remove brake shoe retaining springs.

(7) Remove brake shoe strut and spring from brake support and disconnect brake cable from operating arm.

(8) Compress retainers on end of brake cable housing (Fig. 4) and remove cable from support.

INSTALLING REAR PARKING BRAKE CABLE

When installing a new brake cable, lubricate the cable with short fibre grease at the contact

5-26 PARKING BRAKES

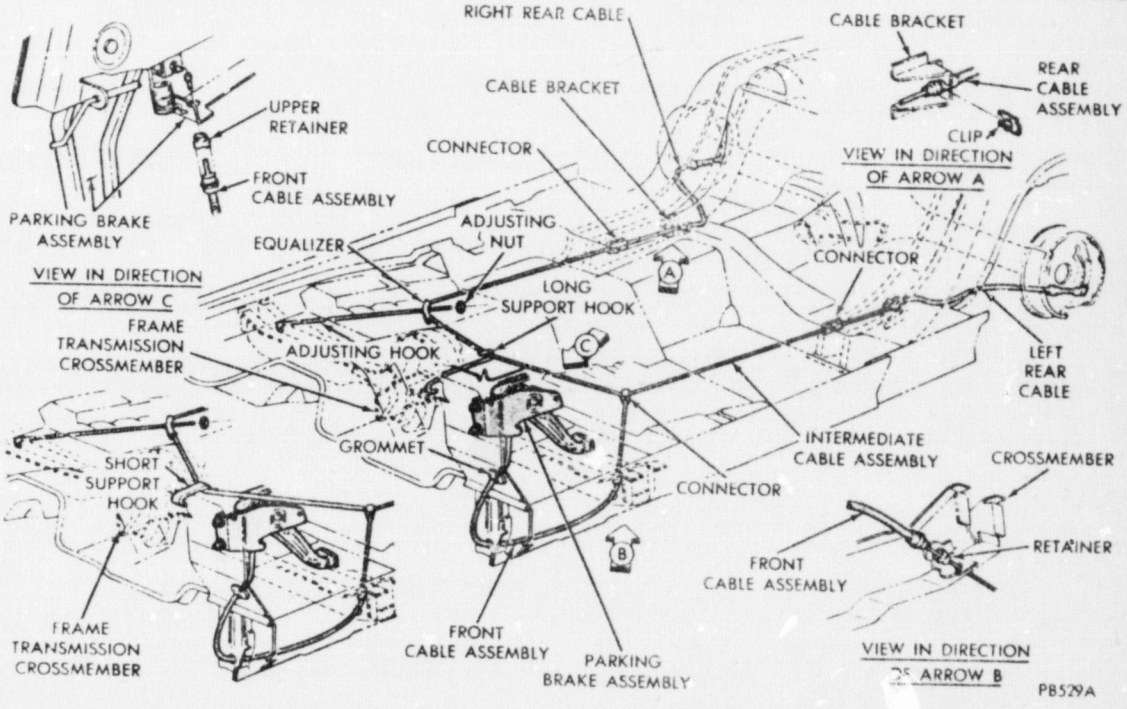

Fig. 2 - Parking Brake Cable Routing (Barracuda and Satellite) - Front Hook, Satellite Models Only

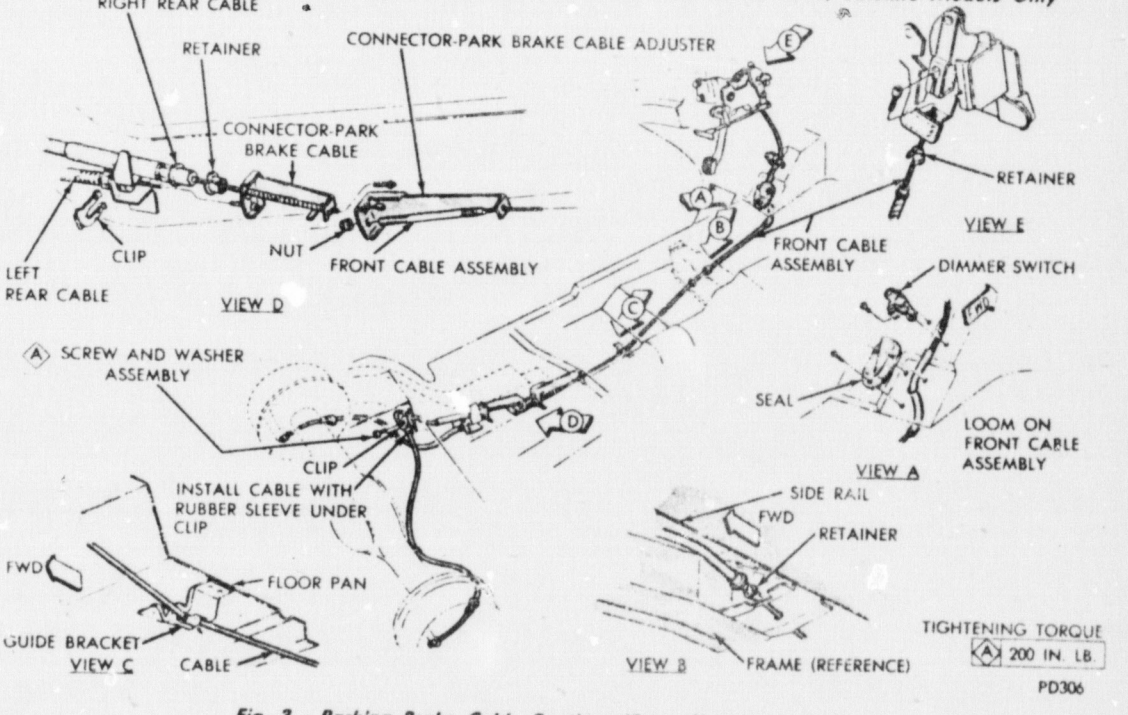

Fig. 3 - Parking Brake Cable Routing (Fury, Chrysler, Imperial)

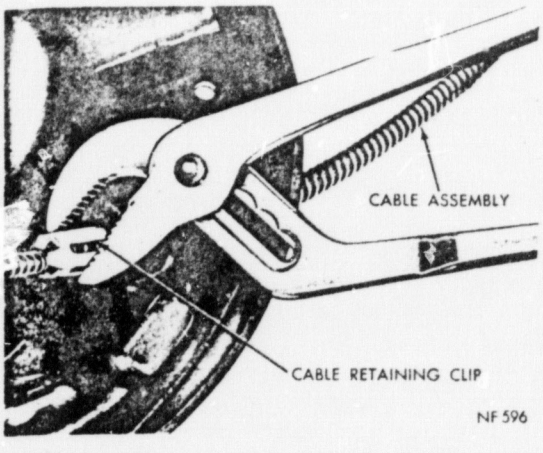

Fig. 4 - Removing Brake Cable From Support

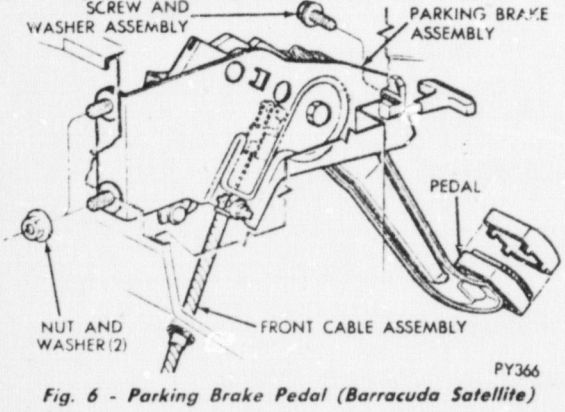

Fig. 6 - Parking Brake Pedal (Barracuda Satellite)

points.

(1) Insert brake cable and housing into brake support plate making certain that housing retainers (Fig. 4) lock the housing firmly into place.

(2) Holding brake shoes in place on support plate, engage brake cable into brake shoe operating lever. Install parking brake strut and spring.

(3) Install brake shoe retaining springs, and brake shoe return springs.

(4) Install brake drum and wheel.

(5) Insert brake cable and housing into cable bracket and install retaining clip.

(6) Insert brake cable into equalizer. Note different size slot for corresponding cable end fitting.

(7) Adjust service brakes and then parking brake cable.

REMOVING FRONT PARKING BRAKE CABLE

(1) Disengage front parking brake cable from equalizer bar (Figs. 1, 2 or 3).

(2) Disengage cable from guide clip.

(3) Using a screwdriver force cable housing and attaching clip out of body crossmember.

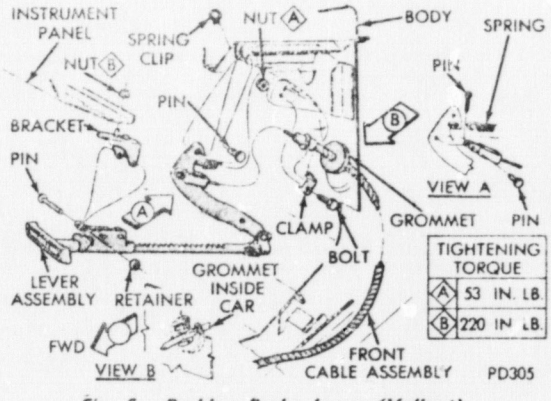

Fig. 5 - Parking Brake Lever (Valiant)

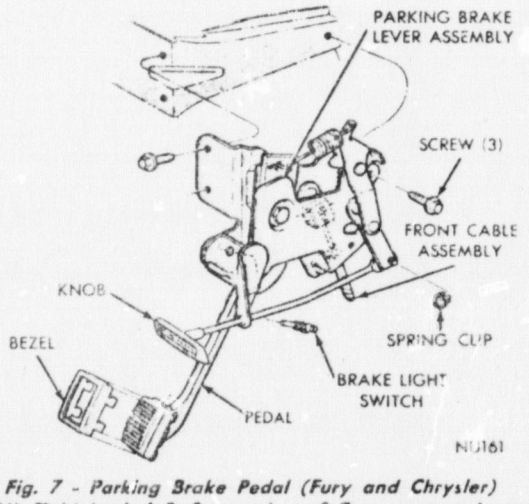

Fig. 7 - Parking Brake Pedal (Fury and Chrysler)

(4) Fold back left front edge of floor mat and remove rubber cable cover from floor pan.

(5) Engage parking brake and work brake cable up and out of brake pedal linkage, (Figs. 5, 6, 7 or 8).

(6) Using a screwdriver, force upper end of cable housing and clip down out of pedal assembly bracket.

(7) Remove cable to floor pan clip and work cable and housing assembly up through floor pan.

INSTALLING FRONT PARKING BRAKE CABLE

(1) Insert parking brake cable down through floor pan.

(2) Install cable housing into underbody mounting bracket.

(3) Insert end fitting of cable into parking brake clevis and force housing and retaining clip into pedal bracket assembly.

(4) Insert cable through crossmember and force housing and retaining clip into crossmember.

(5) Install cable seal.

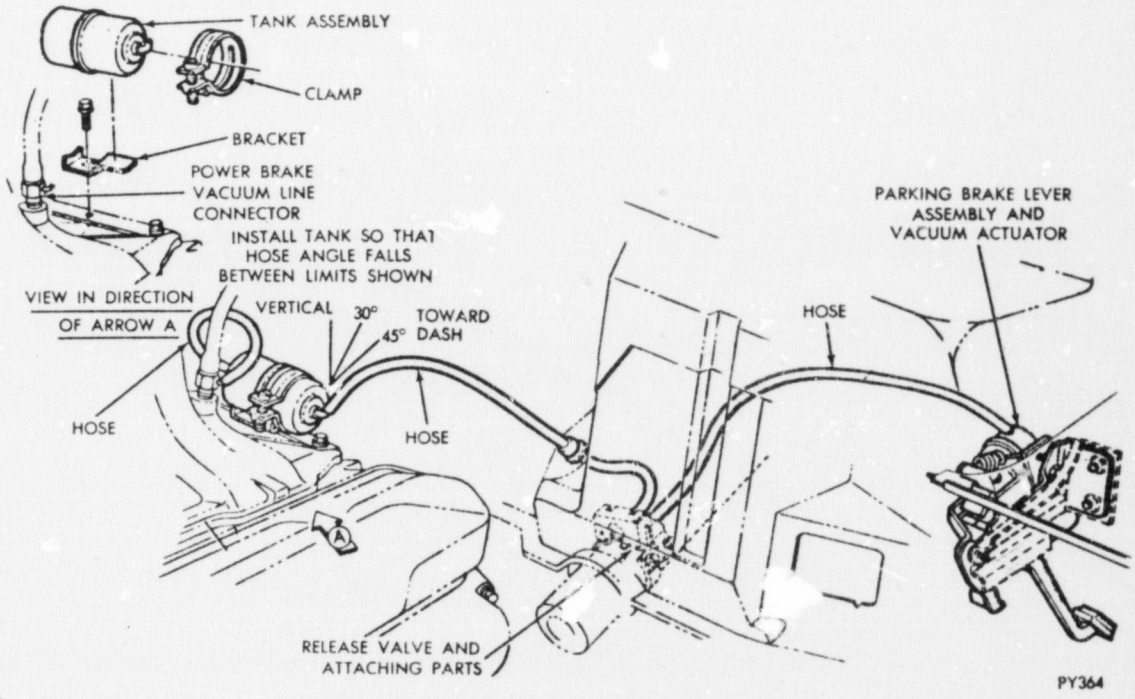

Fig. 8 - Parking Brake Vacuum Valve, Actuator and tank (Imperial)

(6) Attach cable to equalizer and adjust parking brake cable.

(7) Apply brakes several times and test for free wheel rotation.

(8) Test operation of vacuum release valve (Imperial only).

PARKING BRAKE VACUUM VALVE (IMPERIAL)

(1) Place transmission shift selector lever in "Drive" (engine off).

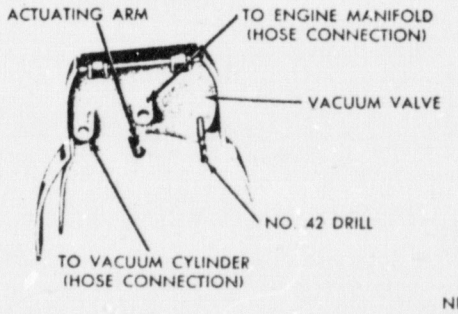

Fig. 9 - Parking Brake Vacuum Valve

(2) Remove vacuum hoses from unit (Fig. 9).

(3) Remove screws that attach vacuum unit to steering column jacket, then remove vacuum valve.

To install vacuum valve unit, (Fig. 9), proceed as follows:

(1) Move actuating arm on valve against spring to extreme position, or until locating holes line up. Install a number 42 drill in hole to properly position valve for installation (Fig. 9).

(2) Move transmission shift selector lever into "Park" position.

(3) Place valve in position on steering column jacket and install attaching screws. (Do not tighten.) Rotate valve clockwise (viewed from drivers position) until actuating arm contacts tab inside steering column jacket. Tighten screws securely.

(4) Remove drill from locating hole.

(5) Install vacuum hoses. (Be sure hose from engine manifold is attached to center fitting on valve (Fig. 9).

(6) Start engine and check to see that parking brake can be set in neutral and park position, and will release in reverse and drive positions.

	(b) Brake pedal linkage binding.	(b) Free up linkage.
	(c) Excessive hydraulic seal friction.	(c) Lubricate seal.
	(d) Compensator port plugged.	(d) Clean out master cylinder.
	(e) Fluid cannot return to master cylinder.	(e) Inspect pedal return.
	(f) Parking brake not returning.	(f) Free up as required.
	(g) Disc brake metering valve malfunction.	(g) Replace metering valve.
	(h) Contaminated brake fluid.	(h) Drain and flush system-replace all rubber parts in hydraulic system.
GRABBING BRAKES	(a) Grease or brake fluid on linings.	(a) Inspect for a leak and replace lining as required.
PEDAL GOES TO FLOOR (OR ALMOST TO FLOOR)	(a) Self-adjusters not operating.	(a) Inspect self-adjuster operations.
	(b) Air in hydraulic system.	(b) Bleed brakes.
	(c) Hydraulic leak.	(c) Locate and correct leak.
	(d) Fluid low in master cylinder.	(d) Add brake fluid.
	(e) Shoe hanging up on rough platform.	(e) Smooth and lubricate platforms.
	(f) Loose disc brake rotor	(f) Check wheel bearing adjustment.
HARD PEDAL (POWER UNIT TROUBLE)	(a) Faulty vacuum check valve.	(a) Replace check valve.
	(b) Collapsed or leaking vacuum hose.	(b) Replace hose.
	(c) Plugged vacuum fittings.	(c) Clean out fittings.
	(d) Leaking vacuum chamber.	(d) Replace unit.
	(e) Diaphragm assembly out of place in housing.	(e) Replace unit.
	(f) Vacuum leak in forward vacuum housing.	(f) Replace unit.

POWER BRAKES

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GENERAL INFORMATION

The power brakes (Figs. 1,2,3 and 4) are self contained vacuum hydraulic power braking units which utilizes engine intake manifold vacuum and atmospheric pressure to provide power assisted application of the vehicle brakes. This provides lighter pedal effort in combination with reduced pedal travel, bringing the brake pedal height down to the approximate height of the accelerator when at closed throttle conditions.

The Midland Ross power brake units can be identified by a clamp type band method of attaching the housing and cover together. Bendix units use a twist lock method of attaching the housing and cover.

The power brake unit mounts on the engine side of the cowl panel and is externally connected to the brake system by a pedal link to the brake pedal, by a vacuum line to the intake manifold (through a check valve) and hydraulic tubes from the master cylinder to the wheel units.

The master cylinder is part of the power brake assembly. This master cylinder contains all of the standard brake master cylinder elements, except for a special push rod which is part of the power brake unit.

SERVICE DIAGNOSIS

Condition	Possible Cause	Correction
DRAGGING BRAKES (ALL WHEELS)	(a) Brake shoes improperly adjusted	(a) Adjust brakes.

MIDLAND-ROSS POWER BRAKE

(Small Tandem Diaphragm)

SERVICE PROCEDURES

REMOVING POWER BRAKE

(1) Remove nuts attaching master cylinder to brake unit. Remove master cylinder from unit.

(2) Disconnect vacuum hose from power brake check valve.

(3) Remove nut attaching brace and support to power unit (Fig. 1).

(4) Remove nut and bolt that attach power brake pedal link to pedal. (Under instrument panel.)

(5) Remove nuts and washers that attach power brake unit to dash panel.

(6) Remove power brake from vehicle.

INSTALLING POWER BRAKE ON VEHICLE

(1) Install new dash panel to power brake gasket.

(2) Position power brake unit on dash panel, then install attaching nuts and washers and tighten to 150 inch-pounds.

(3) Using lubriplate or equivalent, coat the bearing surface of bolt that connects power brake pedal link with brake pedal linkage. Install bolt and nut. Tighten to 30 foot-pounds.

(4) Connect vacuum hose to unit.

(5) Attach brace and support, secure with nut and torque to 150 inch-pounds.

(6) Install master cylinder to front cover mounting studs and tighten nuts to 150 inch-pounds.

With power brake attached to dash panel and vacuum supplied to unit, the master cylinder should compensate (force jet fluid up through front chamber compensation port.)

(7) Check stop light operation.

CAUTION: Do not attempt to disassemble brake booster as this unit will be serviced by Manufacturer's Service Station.

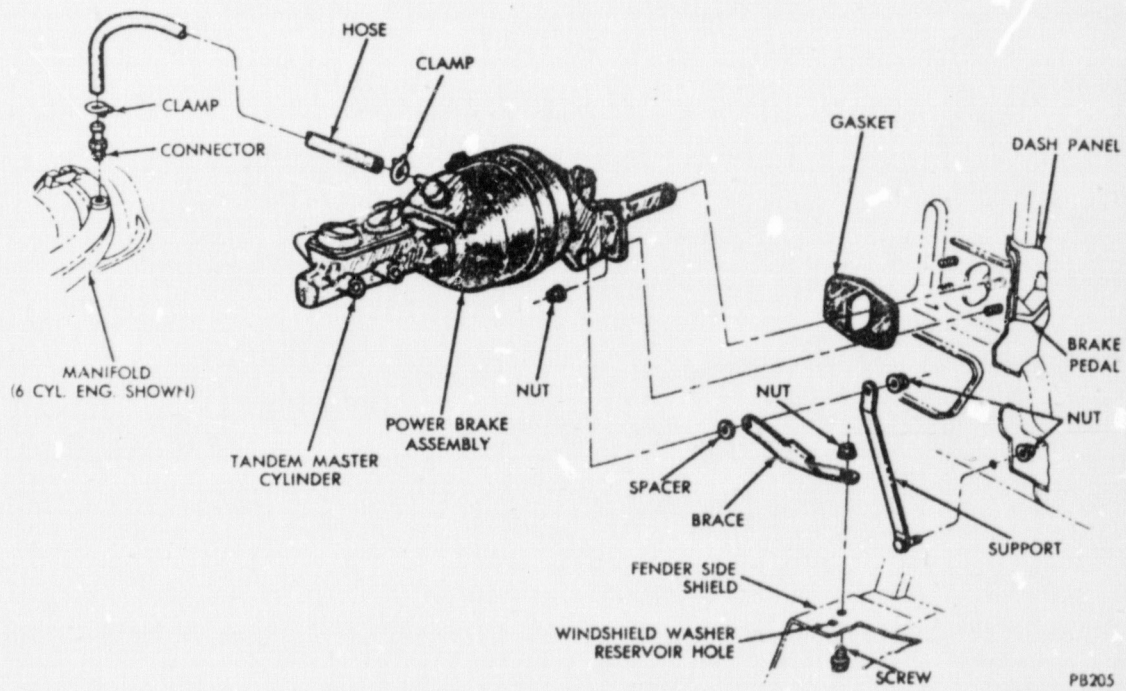

Fig. 1 - Power Brake Assembly (Valiant Models)

POWER BRAKE ASSEMBLY

(Single Diaphragm)

Service Procedures

REMOVING POWER BRAKE

(1) Remove nuts attaching master cylinder to brake unit. Remove master cylinder.

(2) Disconnect vacuum hose from power brake.

(3) From under instrument panel, remove nut and attaching bolt from power brake input push rod and brake pedal blade. On linkage type power brake unit, remove lower pivot retaining bolt (Fig. 2).

(4) Remove four power brake attaching nuts and washers.

(5) Remove power brake, and linkage (if so equipped), from vehicle.

INSTALLING POWER BRAKE

(1) Install power brake assembly into dash and tighten attaching nuts 150 inch-pounds.

(2) Install master cylinder on power brake. Tighten mounting nuts to 150 inch-pounds. With power brake attached to dash panel and vacuum supplied to unit, the master cylinder should compensate (force jet of fluid up through front chamber compensation port).

(3) Connect vacuum hose.

(4) Using lubriplate, or equivalent, coat the bearing surface of bolt that connects power brake pedal link with brake pedal linkage. Install bolt and nut. Tighten to 30 foot-pounds. Connect lower pivot bolt (if so equipped - tighten to 29 foot-pounds.)

(5) Check stop light operation.

CAUTION: Do not attempt to disassemble brake booster as this unit will be serviced by Manufacturer's Service Station.

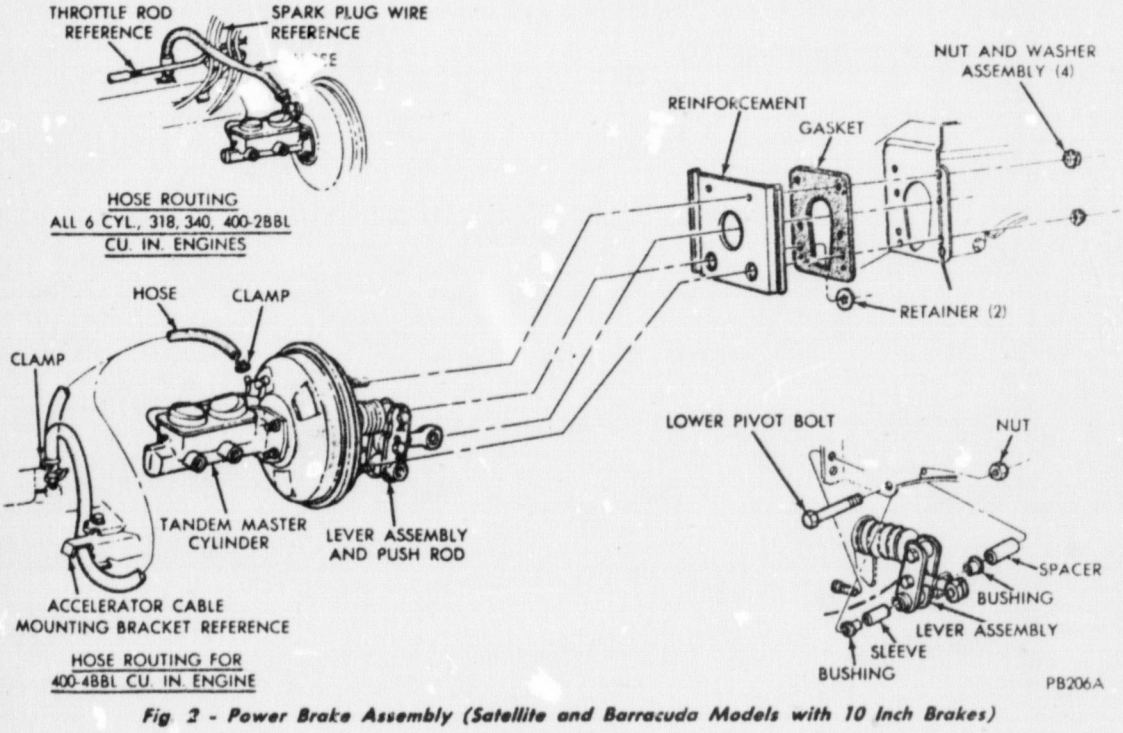

Fig. 2 - Power Brake Assembly (Satellite and Barracuda Models with 10 Inch Brakes)

BENDIX POWER BRAKE

(Large Single Diaphragm)

SERVICE PROCEDURES

REMOVING POWER BRAKE

(1) Remove nuts attaching master cylinder to brake unit. Remove master cylinder from unit.

(2) Disconnect vacuum line from check valve.

(3) From under instrument panel, remove nut and bolt from power brake link and brake pedal (Fig. 3).

(4) From under instrument panel remove four brake unit attaching nuts and washers.

(5) Withdraw brake unit assembly from vehicle.

INSTALLING POWER BRAKE

(1) Install power brake and linkage assembly (if so equipped) into dash panel. Install attaching nuts and washers. Tighten nuts to 150 inch-pounds.

(2) Using lubriplate, coat the bearing surface of bolt that connects power brake pedal link with brake pedal. Install bolt and nut. Tighten to 30 foot-pounds. Install lower pivot bolt (if so equipped - tighten to 29 foot-pounds.)

(3) Attach vacuum hose to check valve.

(4) Install master cylinder on power brake. Tighten mounting nuts to 150 inch-pounds. With power brake attached to dash panel and vacuum supplied to unit, the master cylinder should compensate (force jet of fluid up through front chamber compensation port).

(5) Inspect adjustment of stop light switch.

CAUTION: Do not attempt to disassemble brake booster as this unit will be serviced by Manufacturer's Service Station.

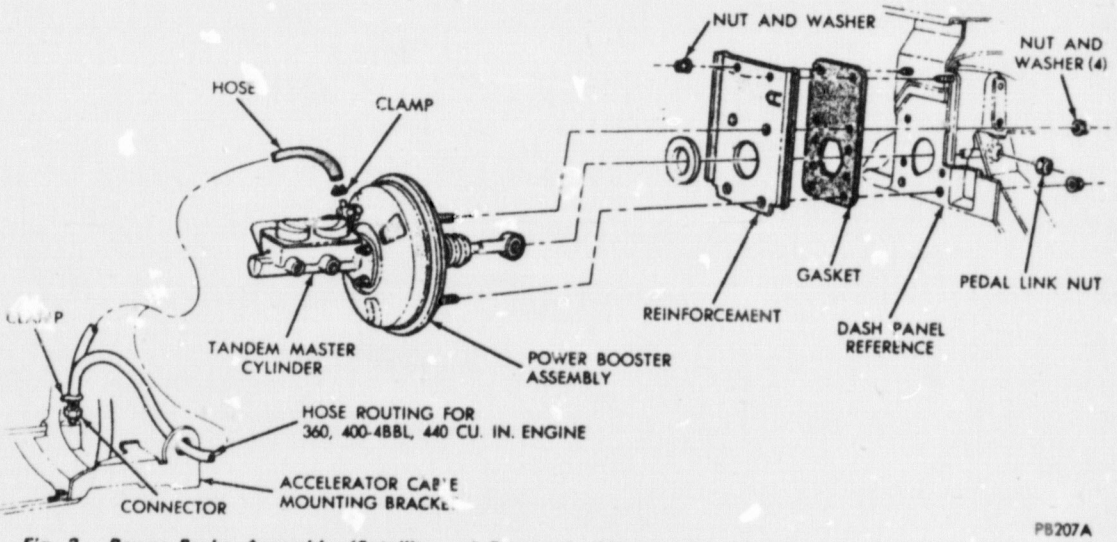

Fig. 3 - Power Brake Assembly (Satellite and Barracuda Models with 11 Inch Brakes) (Fury and Chrysler Models with Automatic Transmission

MIDLAND-ROSS POWER BRAKE

(Large Tandem Diaphragm)

SERVICE PROCEDURES

REMOVING POWER BRAKE

(1) Disconnect master cylinder from power brake unit.

(2) Disconnect vacuum line from check valve.

(3) From under instrument panel, remove push rod nut and bolt from power brake and brake pedal (Fig. 4).

(4) From under instrument panel remove four brake unit attaching nuts and washers.

(5) Withdraw brake unit assembly from brake support bracket.

INSTALLING POWER BRAKE

(1) Install power brake and linkage assembly (if so equipped) into dash panel. Install attaching nuts and washers. Tighten nuts to 150 inch-pounds.

(2) Using lubriplate or equivalent coat the bearing surface of bolt that connects power brake pedal link with brake pedal linkage. Install bolt and nut. Tighten to 30 foot-pounds.

(3) Attach vacuum hose to check valve.

(4) Install master cylinder on power brake. Tighten mounting nuts to 150 inch-pounds. With power brake attached to dash panel and vacuum supplied to unit, the master cylinder should compensate (force jet of fluid up through front chamber compensation port).

(5) Inspect adjustment of stop light switch.

CAUTION: Do not attempt to disassemble brake booster as this unit will be serviced by Manufacturer's Service Station.

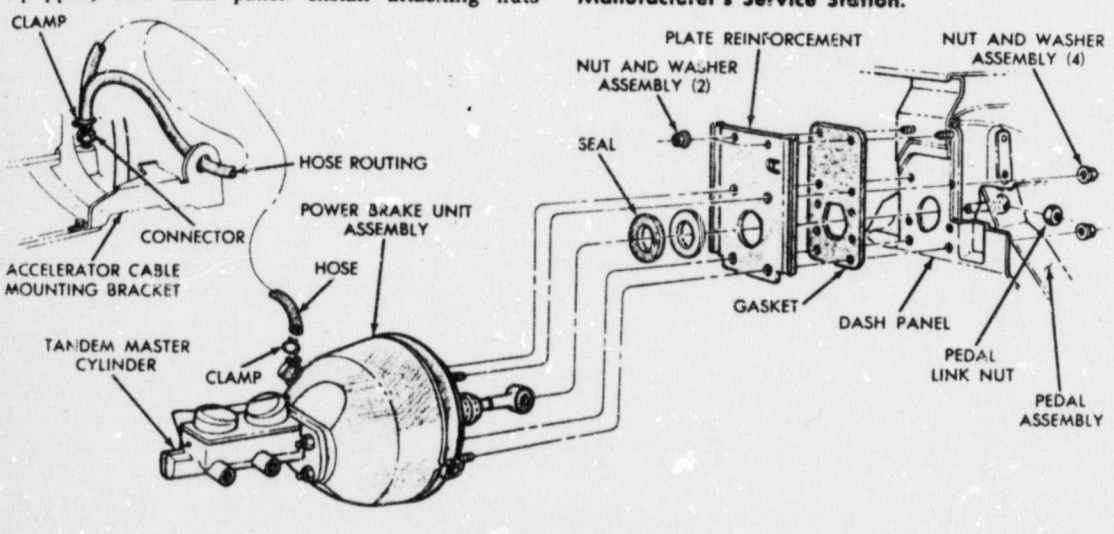

Fig. 4 - Power Brake Assembly (Fury, Chrysler Suburban or Manual Transmission and All Imperial Models)

DISC BRAKES

(FIXED CALIPER)

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GENERAL INFORMATION

The disc brake (Fig. 1) is a fixed caliper, opposed piston, non-energized, ventilated disc type, actuated by the hydraulic system. There is no lateral movement of either the disc or the caliper. The caliper assembly consists of two caliper housings, bolted together. Each half contains two cylinder bores of 1-5/8 inch diameter. Each cylinder contains a seal, piston and externally attached molded rubber dust boot to seal the cylinder from contamination. The pistons are sealed by "rectangular section" rubber piston seals, positioned in grooves machined in the cylinder bores, which provide hydraulic sealing between the pistons (Fig. 2), and the cylinder bores.

The cylinders are connected hydraulically by means of internal passages in the caliper housings and by an external transfer tube between the two halves of the caliper assembly. A bleeder screw and a fluid inlet fitting are provided on each caliper assembly (Fig. 1).

The shoe and lining assemblies are located between parallel machined abutments within the caliper, (Fig. 6) and are supported radially by "ears" on the outer ends of the shoe assemblies. The shoes slide axially in the abutments and ride on machined ledges (bridges) when hydraulic pressure is applied to the pistons. The lining assembly consists of organic friction material, bonded to a metal plate called the shoe, and is replaced as a unit. Brake torque is absorbed by the reaction of the shoe end against the caliper abutments. Two spring clips bolted in the top opening of the caliper act as shoe retaining springs. The caliper is mounted directly to the front wheel spindle and at the rear of the wheel's vertical centerline (Fig. 3).

The cast iron braking disc is of the ventilated type and incorporates cooling fins. This increases the cooling area and permits circulation of air through the disc, resulting in more rapid cooling of the brake. The disc is attached to the wheel hub by five flathead serrated bolts. The outside diameter of the disc is 10.98 inches and the inside is 6.98 inches. A splash shield bolted to the spindle is used to prevent

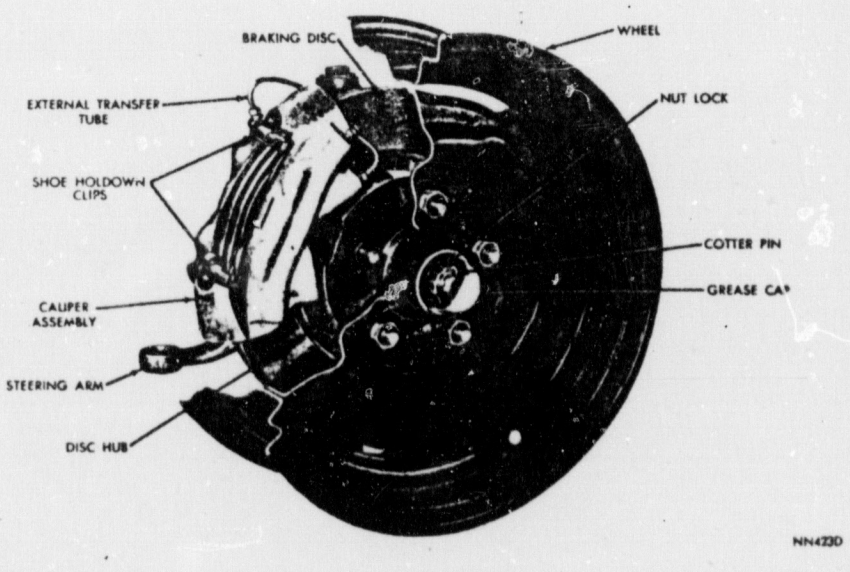

Fig. 1 - Disc Brake Assembly (Sectional)

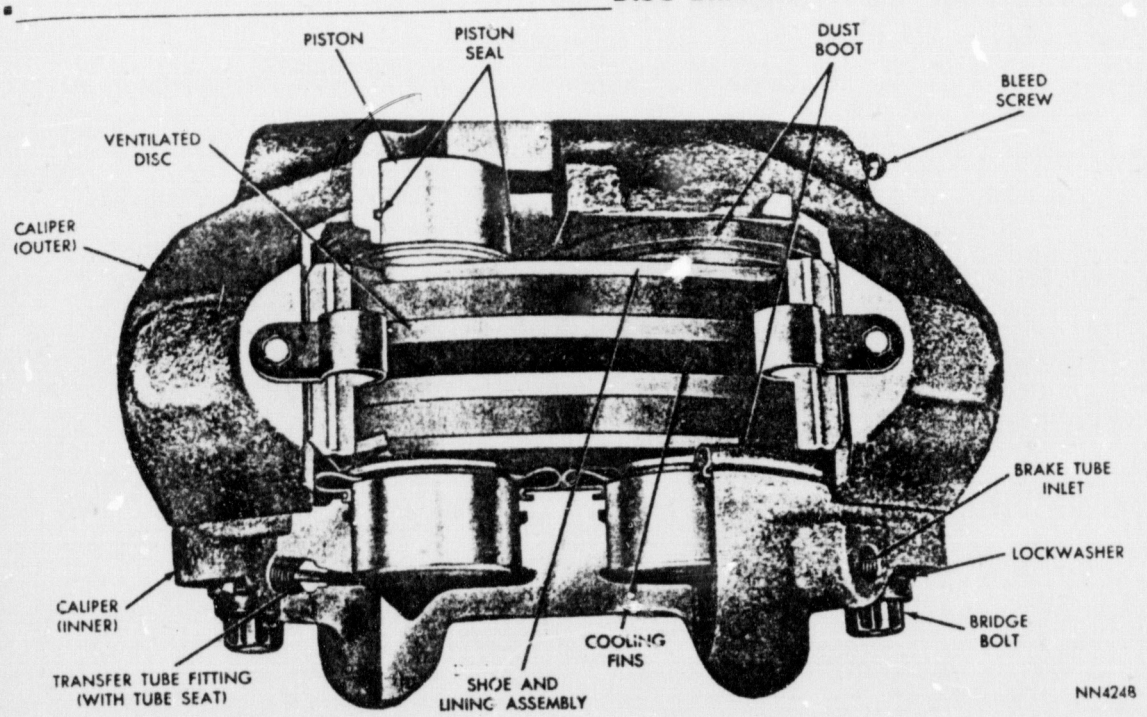

Fig. 2 - Disc Brake Caliper Assembly (Sectional)

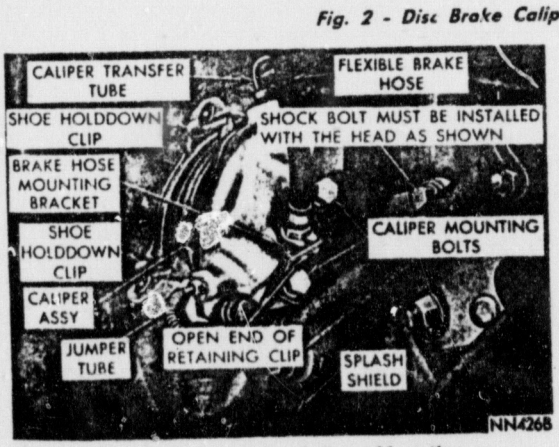

Fig. 3 - Disc Brake Caliper Mounting.

road contaminates from contacting the inboard side of the disc and lining surfaces (Fig. 3). The wheel, itself, provides protection for the outboard surface of the disc.

Braking action begins immediately upon application of the brake pedal as hydraulic pressure from the master cylinder to the system applies pressure to the co-axially aligned caliper pistons forcing the linings against both sides of the braking disc, thus applying the brakes. During brake application, the piston seals are deflected by the hydraulic pressure (Fig. 4). When the pressure is released, the seals re-

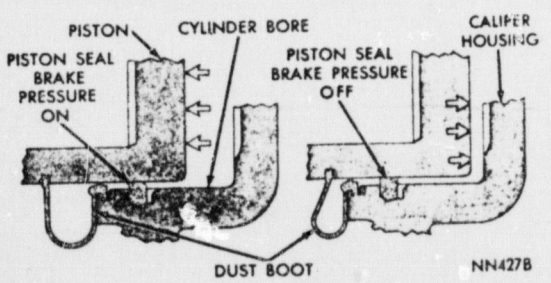

Fig. 4 - Piston Seal Function for Automatic Adjustment

lax or retract, pulling the pistons back from the shoe and lining assemblies approximately .005 in. (This reaction is called "seal retraction" and provides the required running clearance as the linings relieve their force on the disc.) Inherent disc runout also contributes to maintaining running clearance. Automatic adjustment is achieved by the pistons sliding outward from the cylinder bore as the lining wears. The piston assumes a new position relative to the seal and maintains the correct adjustment location at all times (Fig. 4).

There is no residual pressure in the disc brake hydraulic system since the residual pressure valve normally used in drum brake system is located only in the front outlet port of the master cylinder. (See

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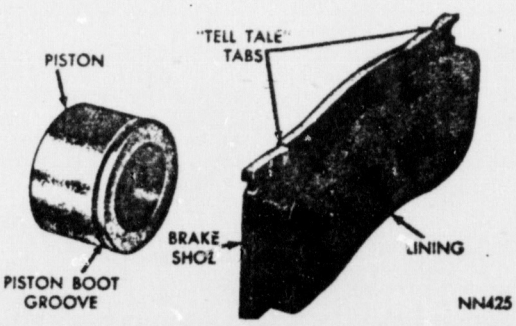

Fig. 5 - Disc Brake Piston, Shoe and Lining Assembly

Master Cylinder Section of the Group).

The hydraulic system contains a proportioning valve between the master cylinder and the rear brake wheel cylinders which provides balanced braking action between the front and rear brakes under a wide range of braking conditions. The valve regulates the hydraulic pressure applied to the rear wheel cylinders, thus limiting rear braking action when high pressures are required at the front brakes. In this manner, premature rear wheel skid is prevented.

An additional feature of this disc brake system is a "tell-tale" tab sounding device which indicates when replacement of the shoe and lining assemblies are required (Fig. 5). The tabs located on the shoes create an audible metallic scraping noise from the brake by metal to metal contact on the braking disc. This warns the driver that the lining has worn to a minimum thickness and the vehicle should be returned to the dealer for relining of the brakes. This device is not detrimental to the function of the braking disc.

PROPORTIONING VALVES

All fixed caliper disc brake equipped vehicle are equipped with a proportioning valve in combination with a brake warning switch, (see "Hydraulic System Control Valves", this Group). The use of the valves is to better match the front disc brakes with the rear drum brakes on the vehicle. This results in improved braking and steering control.

ROUTINE MAINTENANCE

Check Brake Lines and Linings

Raise all four wheels. Remove front wheel and tire assemblies and inspect the braking disc, caliper and linings. Inspect brake flexible hose and tubing according to procedure outlined in paragraph entitled "Brake Hose and Tubing". (The wheel bearings should be inspected at this time and repacked if necessary). **The caliper must be removed to inspect and pack the inner wheel bearings.**

Do not get oil or grease on the disc or the linings. If the linings are worn to within .030 inch of the surface of the shoe, replace both sets of shoe and lining assemblies (inboard and outboard) on the front wheels. It is recommended that both front wheel sets be replaced whenever a respective shoe and lining is worn or damaged.

If the caliper is cracked or fluid leakage through the casting is evident, it must be replaced as a unit.

Shoe and Lining Wear

If a visual inspection does not adequately determine the condition of the lining, a physical check will be necessary.

To check the amount of lining wear, remove the wheel and tire assembly, the spring clips and the shoe and lining assemblies (see "Brake Shoe Removal" paragraph). Three (3) thickness measurements with a micrometer should be taken across the middle section of the shoe and lining; one reading at each side and one reading in the center. When an assembly has worn to a thickness of .180 inch, it should be replaced. If shoes do not require replacement, reinstall making sure to replace to their original inner and outer positions (see "Brake Shoe Installation" paragraph).

When shoe and lining replacement is required, a "scraping" noise from the front brakes will be heard. This noise is metal-to-metal contact between the tabs on the shoe assemblies and the braking disc. When the noise becomes audible to the driver, the lining has worn to the metal tabs and the brakes must be relined. The contact between the metal tab and disc will not affect the functioning of the disc brake system, but continued use until lining is completely worn away will cause disc damage.

Running Clearance

To check the shoe and lining assembly to the braking disc clearance, remove the wheel and tire assembly. Insert a feeler gauge between the lining and the braking disc. Ordinarily, the clearance should be .003 to .006 inch. However, if the vehicle was stopped by a brake application just prior to checking the clearance, it is considered normal for the brakes to drag slightly.

Brake Roughness

The most common cause of brake chatter on disc brakes is a variation in thickness of disc. If roughness or vibration is encountered during highway operation or if pedal pumping is experienced at low speeds, the disc may have excessive thickness variation. To check for this condition, measure the disc at 12 (twelve) points with a micrometer at a radius approximately one inch (1 in.) from edge of disc. If thickness measurements vary by more than .0005 inch the disc should be replaced with a new one.

Braking Disc Runout

Excessive lateral runout of the braking disc will cause a "knocking back" of the pistons, which will create increased pedal travel and vibration when the brakes are applied.

Before checking the runout, the wheel bearing end play should be eliminated by tightening the adjusting nut. **The readjustment is very important and will be required at the completion of the test to prevent bearing failure.** After tightening the adjusting nut, be sure that the braking disc can still be rotated.

Dial indicator C-3339 should be clamped to the steering knuckle so that the stylus contacts the braking disc at a point approximately one (1) inch from the outer edge, (Fig. 15). Rotate the disc and check the indicator reading. The maximum total indicator reading on the gauge should not exceed .0025 inch. If the reading exceeds this specification, the disc should be replaced. **Do not attempt to refinish a disc that indicates runout in excess of the specification.**

BRAKE HOSE AND TUBING

Installation of Brake Hose

The flexible hydraulic brake hose should **always** be installed on the vehicle by first tightening the male end of the hose into caliper, wheel cylinder, or rear axle housing tee. The hose should then be attached to the hose bracket in a manner to give minimum twist. (15 degree twist is the maximum recommended). Excessive twist can result in hose interference problems with possible hydraulic system failure.

Inspection of Brake Hose and Tubing

Inspection of brake hose and tubing should be included in all brake service operations and every 6 months or 6,000 miles (every 3 months or 4,000 miles for vehicles used in fleet service; Police, Taxi, etc.). The hoses should be checked for:

(1) Correct length, severe surface cracking, pulling scuffing or worn spots. **(Should the fabric casing of the hose be exposed by cracks or abrasions in the rubber hose cover, the hose should be replaced).** Eventual deterioration of the hose can take place with possible burst failure.

(2) Faulty installation to cause twisting, wheel, tire or chassis interference.

Always use factory recommended hose to insure quality, correct length and superior fatigue life. Care should be taken to make sure that the tube and hose mating surfaces are clean and free from nicks and burrs. New copper seal washers should be used and the tube nuts and connections should be properly made and tightened. Double wall steel tubing should always be used to insure superior fatigue life. Care should be taken when replacing brake tubing, to use the proper bending and flaring tools and to avoid routing the tubes against sharp edges, moving components or in hot areas. All tubes should be properly attached with recommended retaining clips.

DISC BRAKE SERVICE PRECAUTIONS

(1) Grease or any other foreign material must be kept off the caliper assembly, surfaces of the braking disc and external surfaces of the hub, during service procedures. Handling the braking disc and caliper should be done in a way to avoid deformation of the braking disc and nicking or scratching the brake linings.

(2) If inspection reveals the square sectioned rubber piston seals are worn or damaged, they should be replaced immediately.

(3) During removal and installation of a wheel and tire assembly, exercise care so as not to interfere with or damage the bleeder screw or the transfer tube.

(4) The front wheel bearing end play is important and must be within specifications.

(5) Be sure vehicle is centered on the hoist before servicing any of front end components to avoid bending or damaging disc splash shield on full right or left wheel turns.

(6) Before vehicle is moved after any brake service work, **be sure and obtain a firm brake pedal.**

(7) The assembly bolts of two caliper housings should not be disturbed, unless servicing of caliper assembly is required.

(8) **Riding brake pedal** (common left foot application) should be avoided during vehicle operation.

(9) The wheel, tire, hub and disc assembly **cannot** be removed as an assembly. The caliper assembly must be removed before removal of hub and disc assembly.

SERVICE DIAGNOSIS

Condition	Possible Cause	Correction
EXCESSIVE PEDAL TRAVEL	(a) Rear brake adjustment required. (b) Air leak, or insufficient fluid in system or caliper.	(a) Check and adjust rear brakes. (b) Check system for leaks.

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SERVICE DIAGNOSIS

Condition	Possible Cause	Correction
	(c) Warped or excessively tapered shoe and lining assembly.	(c) Install new shoe and linings.
	(d) Excessive disc runout.	(d) Check disc for runout with dial indicator. Install new disc.
	(e) Loose wheel bearing adjustment.	(e) Readjust wheel bearings to specified torque.
	(f) Improper brake fluid (boil).	(f) Drain and install correct fluid.
	(g) Damaged caliper piston seal.	(g) Install new piston seal.
BRAKE ROUGHNESS OR CHATTER (Pedal Pulsating)	(a) Excessive out-of-parallelism of braking disc.	(a) Check disc for thickness variation using a micrometor.
	(b) Rear brake drums out-of-round.	(b) Loosen and retorque wheel nuts to specifications.
	(c) Excessive lateral runout of braking disc.	(c) Check disc for lateral runout with dial indicator. Install new disc.
	(d) Excessive front bearing clearance.	(d) Readjust wheel bearings to specified torque.
	(e) Rear brake drums distorted by improper tightening of nuts.	(e) Check drums for out-of-round and reface if necessary.
EXCESSIVE PEDAL EFFORT	(a) Power brake malfunction.	(a) Replace
	(b) Frozen or seized pistons.	(b) Disassemble caliper and free up pistons. Clean parts.
	(c) Shoe and lining worn below .180 in. (Lining only— .30 in.)	(c) Install new shoe and linings.
	(d) Brake fluid, oil or grease on linings.	(d) Install new shoe linings as required.
	(e) Incorrect lining.	(e) Remove lining and install correct lining.
PULL	(a) Loose calipers.	(a) Tighten caliper mounting bolts from 45 to 60 ft. pounds.
	(b) Frozen or seized pistons.	(b) Disassemble caliper, use light sanding to remove roughness and loose particles, clean seal groove and install new pistons, seals, and boots.
	(c) Rear brake pistons sticking.	(c) Free up rear brake pistons.
	(d) Front end out of alignment.	(d) Check and align front end.
	(e) Broken rear spring.	(e) Install new rear spring.
	(f) Out-of-round rear drums.	(f) Check and reface drums if necessary.
	(g) Incorrect tire pressure.	(g) Inflate tires to recommended presures.
	(h) Brake fluid, oil or grease on linings.	(h) Install new shoe and linings.
	(i) Restricted hose or line.	(i) Check hoses and lines and correct as necessary.
	(j) Rear brakes out of adjustment.	(j) Adjust rear brakes.
	(k) Unmatched linings.	(k) Install correct lining.
	(l) Distorted brake shoes.	(l) Install new brake shoes.
NOISE Groan—Brake noise emanating when slowly releasing brakes (creep—groan)	(a) Not detrimental to function of disc brakes—no corrective action required. (Indicate to operator this noise may be eliminated by slightly increasing or decreasing brake pedal efforts).	

SERVICE DIAGNOSIS

Condition	Possible Cause	Correction
RATTLE-Brake noise or rattle emanating at low speeds on rough roads, (front wheels only)	(a) Excessive clearance between shoe and caliper.	(a) Install new shoe and lining assemblies.
SCRAPING—	(a) Loose wheel bearings.	(a) Readjust wheel bearings to correct specifications.
	(b) Braking disc rubbing housing.	(b) Check for rust or mud buildup on caliper mounting and bridge bolt tightness.
	(c) Mounting bolts too long.	(c) Install mounting bolts of correct length.
FRONT BRAKES HEAT UP DURING DRIVING AND FAIL TO RELEASE	(a) Residual pressure valve in master cylinder.	(a) Remove valve from cylinder.
	(b) Frozen or seized piston.	(b) Disassemble caliper, use light sanding to remove roughness and loose particles, clean seal groove and install new pistons, seals and boots.
	(c) Operator riding brake pedal.	(c) Instruct owner how to drive with disc brakes.
	(d) Sticking pedal linkage.	(d) Free up sticking pedal linkage.
	(e) Power brake malfunction.	(e) Replace
LEAKY WHEEL CYLINDER	(a) Corroded bore.	(a) Hone bore and replace boots and cups.
	(b) Damaged or worn caliper piston seal.	(b) Disassemble caliper and install new seal.
	(c) Scores or corrosion on surface of piston.	(c) Disassemble caliper and hone cylinder bore. If neccessary, install new pistons.
GRABBING OR UNEVEN BRAKING ACTION	(a) Causes listed under "Pull."	(a) Corrections listed under "Pull."
	(b) Power brake malfunction.	(b) Replace unit.
BRAKE PEDAL CAN BE DEPRESSED WITHOUT BRAKING EFFECT	(a) Air in hydraulic system or improper bleeding procedure.	(a) Bleed system.
	(b) Leak in system or caliper.	(b) Check for leak and repair as required.
	(c) Pistons pushed back in cylinder bores during servicing of caliper (shoe and lining not properly positioned).	(c) Reposition brake shoe and lining assemblies. Depress pedal a second time and if condition persists, check following causes:
	(d) Leak past piston cups in master cylinder.	(d) Recondition master cylinder.
	(e) Damaged piston seal in one or more of cylinders.	(e) Disassemble caliper and replace piston seals as required.
	(f) Leak in rear brake cylinder.	(f) Hone cylinder bore. Install new piston cylinder cups.
	(g) Rear brakes out of adjustment.	(g) Adjust rear brakes.
	(h) Bleeder screw open.	(h) Close bleeder screw and bleed entire system.

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SERVICE PROCEDURES

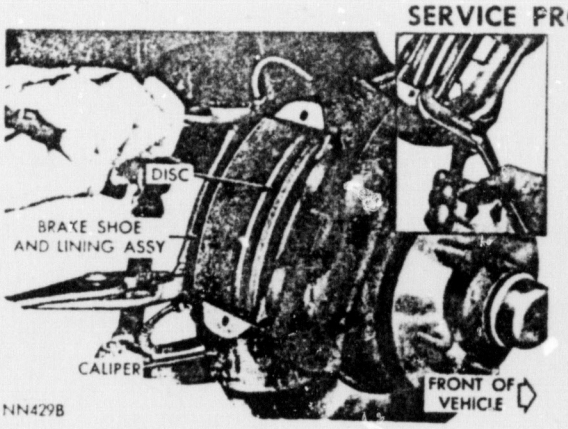

Fig. 6 - Removing Brake Shoe and Lining

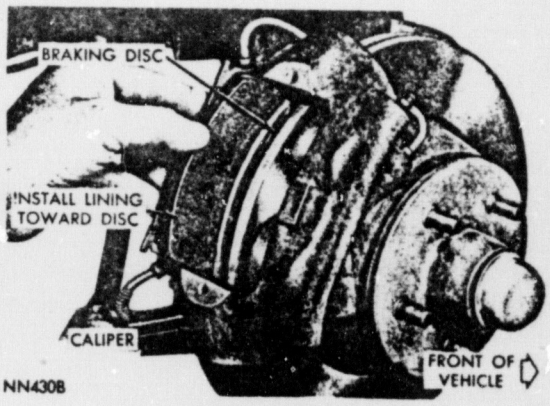

Fig. 7 - Installing Brake Shoes and Lining

BRAKE SHOE REMOVAL

To remove the disc brake shoe and lining assembly, (Fig. 1), proceed as follows:

(1) Raise vehicle on a hoist or jackstands.

(2) Remove wheel covers, and wheel and tire assembly.

(3) Remove shoe retainer hold down clips.

(4) Using two pair of pliers, grasp tabs on outer ends of shoes, remove shoe and lining by pulling outward (Fig. 6). Due to a ridge of rust that may build up on rotor surface outside of lining contact area, it may be necessary to force piston back slightly into bores. Pistons can be forced back into bores by forcing shoe back with a water pump pliers placed on corner of the shoe and caliper housing (Fig. 6).

Check the caliper for seal leaks (evident by fluid moisture around the cavity) and for any damage to the piston dust boot. Wipe the cavity clean (between the inner and outer caliper housings) with a shop towel. Check the piston dust boot for proper seating in the piston bore and the caliper housing. If excessive fluid moisture is evident, it will be necessary to install a new piston seal and piston dust boot. (Refer to "Disassembling the Caliper" paragraph.)

BRAKE SHOE INSTALLATION

(1) Push all pistons back into their bores until bottomed to allow for installation of new thick shoes. This can be done by placing a flat sided metal bar or tool against piston and exerting a steady force until bottomed. This will cause fluid to rise in the master cylinder reservoir so be sure and remove a quantity of fluid from the reservoir before hand.

(2) Slide new shoe and lining into caliper with ears of shoe resting on bridges of caliper (Fig. 7). Be sure shoe is fully seated and lining is facing disc.

(3) Slide remaining shoe and lining into caliper, using same procedure as described above.

(4) Place shoe retainer spring assemblies in position on caliper.

(5) Pump brake pedal several times until a firm pedal has been obtained and shoe and lining have been properly seated.

(6) Install wheel and tire. Tighten wheel stud nuts using a star pattern (skip every other nut going around) until all 5 are torqued to 55 foot-pounds. Install wheel cover.

(7) Check and refill master cylinder reservoir with brake fluid as required.

CAUTION: Road test the vehicle and make several stops to wear off any foreign material on the brakes and to seat the linings. The vehicle may pull to one side or the other if this is not done.

REMOVING CALIPER

Should it become necessary to remove the caliper for installation of a new piston seal or boot, (Fig. 4), proceed as follows:

(1) Raise car on hoist or jackstands.

(2) Remove wheel cover and wheel and tire assembly.

(3) Disconnect front brake flexible hose from brake tube at frame mounting bracket. (Plug brake tube to prevent loss of fluid.

(4) Remove bolts that attach caliper assembly to steering knuckle. Should it become necessary to install a new flexible brake hose on a disc brake equipped vehicle, scribe a mark on hose bracket on side where hose enters, and position of hose retaining clip underneath (Fig. 3). **Be sure at reassembly, that open end of retaining clip is facing out and away from caliper.**

(5) Slowly slide caliper assembly up and away

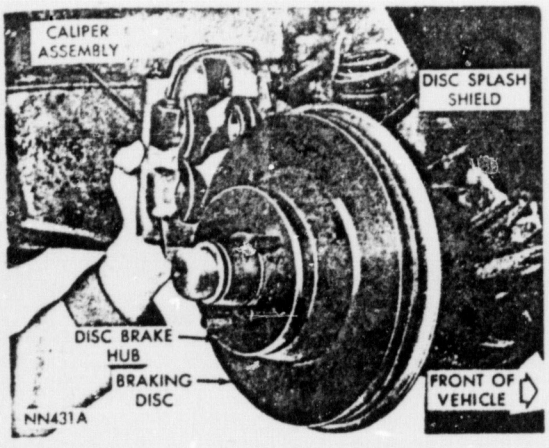

Fig. 8 - Removing or Installing Disc Brake Caliper

from brake disc (Fig. 8) and remove to bench for disassembly.

DISASSEMBLING CALIPER

To disassemble the caliper for the installation of new parts (Fig. 9), proceed as follows:

(1) Remove shoe retainer spring clips. Remove transfer tube (armored) at caliper.

(2) Mount caliper assembly in a vise equipped with protector jaws. (Use caliper mounting lugs.) Remove transfer tube.

(3) Remove shoe and lining assemblies.

(4) Remove bridge bolts that hold two halves of caliper together. **(Make sure at reassembly that these two bolts are used and tightened to correct torque.)** Separate assemblies.

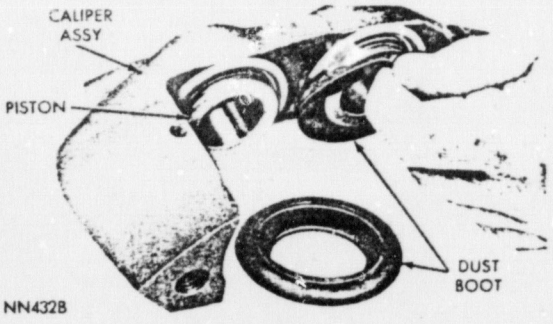

Fig. 10 - Removing Dust Boot from Piston and Caliper

(5) Peel dust boot out and away from caliper housing retainer and out of piston groove (Fig. 10). Remove remaining dust boots in same manner.

(6) Using Tool C-3999, remove each of pistons (Fig. 11). **Care must be used so as not to scratch, burr or otherwise damage piston on outside diameter.** To do so effects sealing qualities of piston. Draw piston straight out of its bore. If a piston becomes cocked, removal is more difficult and piston or bore may be damaged.

(7) Using a small pointed wooden or plastic tool, remove piston seals from groove in cylinder bore (Fig. 12). Discard old seals. (Use care so as not to scratch bore or the seal groove.)

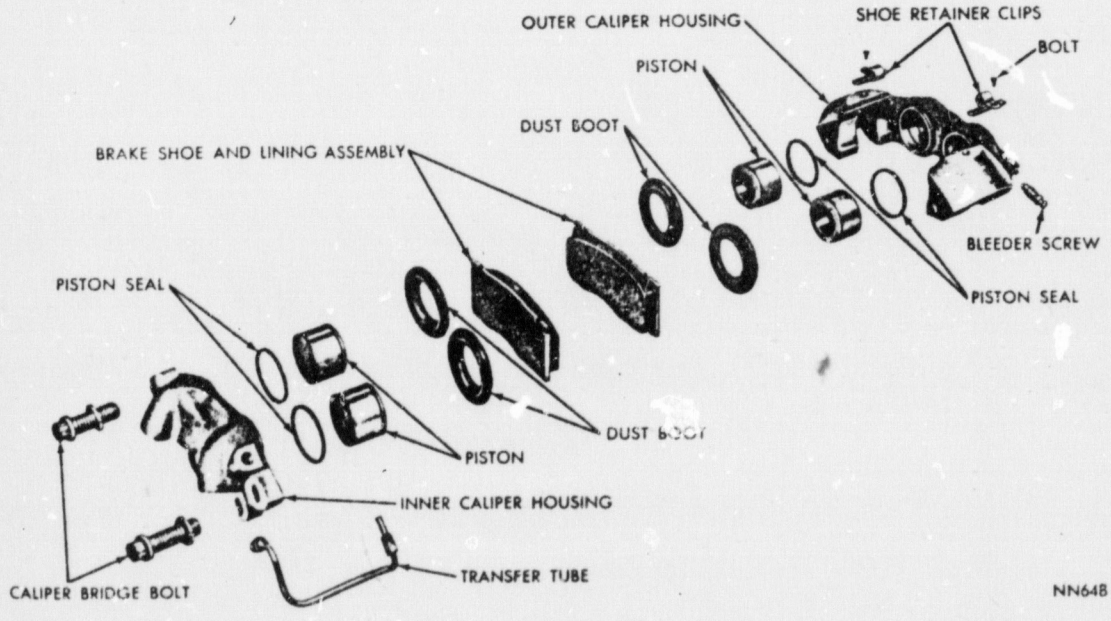

Fig. 9 - Caliper Assembly (Exploded View)

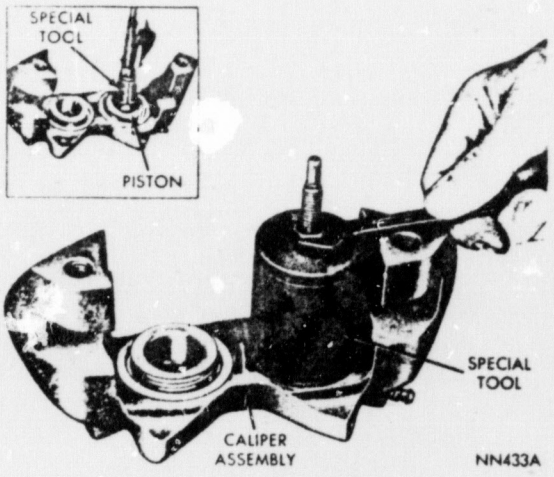

Fig. 11 - Removing Pistons from Caliper

Fig. 13 - Honing Piston Bores

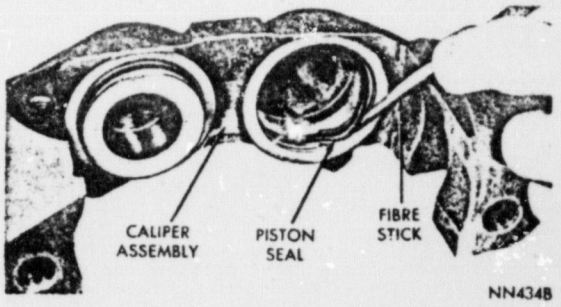

Fig. 12 - Removing Piston Seals from Caliper

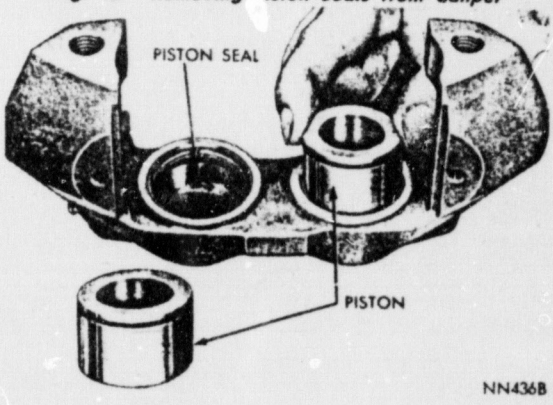

Fig. 14 - Installing Pistons in Caliper

CLEANING AND INSPECTION

Clean all parts in brake fluid and wipe dry, using clean, lint free, shop towels. Using an air hose, blow out the drilled passages and bores. Check the dust boots for punctures or tears. If punctures or tears are evident, new boots should be installed at reassembly. Inspect the piston bores in both housings for scoring or pitting. Install a new piston if it is pitted, scored or the chrome plating is worn off. Bores that show light scratches or corrosion, can usually be cleaned with crocus cloth. However, bores that have deep scratches or scoring may be honed, using Tool C-3993, providing the diameter of the bore is not increased more than .002 inch. If the bore does not clean up within this specification, a new caliper housing should be installed. (Black stains on the bore walls are caused by the piston seals and will do no harm.)

When using hone C-3993 (Fig. 13) be sure and install the hone baffle before honing bore. The baffle is used to protect the hone stones from damage. After honing the bore carefully, clean the seal groove with a stiff non-metallic rotary brush.

Use extreme care in cleaning the caliper after honing. Remove all dust and grit by flushing the caliper with brake fluid; wipe dry with a clean lintless cloth and then clean a second time in the same manner.

ASSEMBLING CALIPER

To reassemble the disc brake caliper, (Fig. 9), proceed as follows:

(1) Clamp inner caliper half in a vise (with protector jaws) by mounting lugs.

(2) Dip new piston seals in clean brake fluid and install in caliper grooves. The seal should be positioned at one area in groove and gently worked around cylinder bore with a finger until properly seated. **Never use an old piston seal.** (Be sure seals are not twisted or rolled.)

(3) Coat outside diameter of pistons with clean brake fluid and install them in cylinder bores (Fig. 14), with open end of piston and boot retaining groove facing out of cylinder.

(4) Position piston squarely in bore and apply slow steady pressure until piston is positioned. **If piston will not position itself, remove piston and check position of seal for proper position in groove.**

(5) Install a new dust boot in position in groove in caliper and in piston. **Be sure dust boot is properly seated.** Install new remaining dust boots in

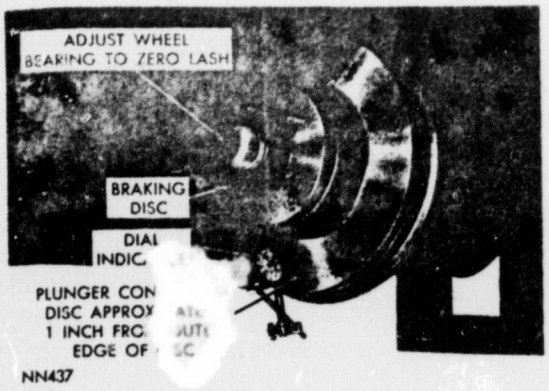

Fig. 15 - Checking Braking Disc Run-out

same manner.

(6) Install caliper half on one clamped in vise, then install assembly bolts (bridge bolts) and tighten from 70 to 80 foot-pounds. **(Under no condition should these bolts be substituted or replaced by an inferior bolt. The use of bolts other than those specified for this purpose, could cause a caliper failure resulting in an accident).**

(7) Install transfer tube and tighten securely. (Be sure tube is under protective eyebrow.)

(8) Install bleeder screw but do not tighten.

INSTALLING CALIPER

Before installing the caliper assembly over the brake disc, check the disc for runout and thickness variation. Mount a dial indicator (Fig. 15) and check the lateral runout. Runout should not exceed .0025 inch. If runout exceeds the specified figure, remove the disc and install a new one. (Be sure the wheel bearings are adjusted to zero lash during this check.) Readjust wheel bearings after check.

Thickness variation of the disc, measure the disc at 12 (twelve points) with a micrometer at a radius approximately one inch (1 in.) from edge of disc. If thickness measurements vary by more than .0005 inch, the disc should be replaced with a new one.

(1) Install caliper assembly over disc and align mounting holes. Install mounting bolts and tighten from 50 to 80 foot-pounds. **A check should be made to be sure that braking disc runs squarely and centrally within caliper opening. There should be approximately .090 to .120 inch clearance between outside diameter of braking disc and caliper. There should also be a minimum of .050 inch from either disc face to machined groove in outboard caliper.**

(2) Install shoe and lining assemblies between caliper and braking disc.

(3) Install shoe retainer springs in position on caliper.

(4) Open bleeder screw, then reconnect brake line at caliper housing. Allow caliper to fill with brake fluid; then, close bleeder screw. (Be sure all air bubbles have escaped; bleeding caliper.) Replenish brake fluid in master cylinder.

(5) **"Pump" brake pedal several times to actuate piston seals and position shoe and lining assemblies.**

(6) After assembling caliper unit be sure and check for fluid tightness under maximum pedal pressures. (Recheck master cylinder reservoir level.) **Check and be sure that lower shock absorber mounting bolt has been installed from rear and nut toward front of vehicle. This is important (Fig. 3).**

(7) Install wheel and tire assembly and tighten wheel stud nuts (in a star pattern) to 30 foot-pounds, then to 55 foot-pounds. **This is important.**

(8) Remove jackstands or lower hoist.

CAUTION: Road test the vehicle and make several stops to wear off any foreign material on the brakes and to seat the linings. The vehicle may pull to one side or the other if this is not done.

REMOVING BRAKING DISC AND HUB

Should it become necessary to remove the braking disc for installation of a new disc, proceed as follows:

(1) Remove wheel cover and wheel and tire assembly.

(2) Remove caliper assembly as described under "Removing Caliper" paragraph, (but do not disconnect brake line). Suspend caliper from wire hook or loop to avoid strain on hose and damage to transfer tube.

(3) Remove grease cup, cotter pin, nut lock, nut, thrust washer and outer wheel bearing.

(4) Pull disc and hub off wheel spindle.

INSTALLING BRAKING DISC AND HUB

(1) Slide brake disc and hub assembly on spindle.

(2) Install outer bearing, thrust washer, and nut.

(3) Tighten wheel bearing adjusting nut to 90 inch-pounds while rotating hub and disc.

(4) Position lock nut on nut with one pair of slots in line with cotter pin hole.

(5) Back off adjusting nut and lock assembly one slot then install cotter pin. The resulting adjustment should be zero (no preload) end play. (This is very important, when checking disc runout.)

(6) Install a dial indicator C-3339 (Fig. 15) and check runout of disc on both sides. The runout should not exceed .0025 inch. Readjust wheel bearing clearance after checking braking disc runout.

(7) Clean grease cap, coating inside with wheel grease (do not fill) and install cap.

(8) Install caliper assembly as described in "Installing the Caliper" paragraph.

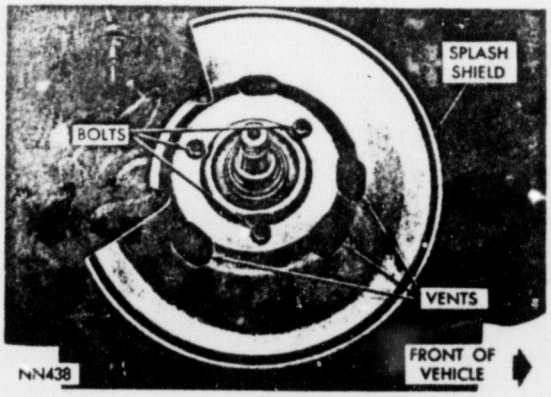

Fig. 16 - Disc Splash Shield Mounting

(9) Install wheel and tire assembly and wheel cover.
(10) Remove jackstands or lower hoist.
(11) Road test vehicle as described in "Brake Shoe Installation" paragraph.

REMOVING SPLASH SHIELD

Should it become necessary to remove the braking disc splash shield because of damage or the installation of the steering knuckle, proceed as follows:
(1) Raise vehicle on a hoist or jackstands.
(2) Remove wheel cover and wheel and tire assembly.
(3) Remove caliper assembly, as described under "Removing Caliper" paragraph. Do not disconnect brake line.
(4) Remove grease cup, cotter pin, nut lock, nut, thrust washer and outer wheel bearing.
(5) Pull braking disc and hub off wheel spindle.
(6) Remove bolts that attach splash shield (Fig. 16) to steering knuckle.

INSTALLING SPLASH SHIELD

To install the braking disc splash shield, (Fig. 16), proceed as follows:
(1) Position styrafoam gasket and install splash shield in position on steering knuckle, with cutout section toward rear.
(2) Align mounting holes and install attaching bolts. Tighten to 220 inch-pounds.
(3) Reinstall braking disc and hub assembly. Install outer bearing, thrust washer and nut. Tighten front wheel bearing as described previously. Install nut lock, cotter pin and grease cap.
(4) Install caliper assembly as described under "Installing Caliper" paragraph.
(5) Install wheel and tire. Tighten wheel stud nuts (in a star pattern) to 30 foot-pounds, then to 55 foot-pounds. Install wheel cover.
(6) Remove jackstands or lower hoist.

BLEEDING DISC BRAKE

The disc brake hydraulic system can be bled (preferably) **with pressure bleeding equipment**. On disc brake equipped vehicles, the brake pedal will require more pumping, and frequent checking of the fluid level in the master cylinder during the bleeding operation, if pressure bleeding equipment is not used.

It will be necessary to remove the front wheel and tire assemblies in order to gain access to the bleeder screw, located on the outboard caliper housing at the top (Fig. 1).

Never use brake fluid that has been drained from the hydraulic system, when bleeding the brakes.

On vehicles equipped with disc brakes, be sure that the disc brake pistons are returned to their normal positions and that the shoe and lining assemblies are properly seated.

Before driving the vehicle, check the operation of the brakes to be sure that a firm pedal has been obtained.

(1) Remove wheel covers, then raise vehicle using a hoist or jackstands.
(2) Remove wheel and tire assemblies.
(3) Bleed the front brakes first, then proceeding to the right rear and left rear in order.

After bleeding the brakes, proceed as follows:
(1) Install wheel and tire assemblies, tightening wheel stud nuts to 55 foot-pounds.
(2) Install wheel covers.
(3) Remove jackstands or lower hoist.

BALANCING FRONT WHEELS (DISC BRAKE EQUIPPED VEHICLES)

To balance front wheels on a disc brake equipped vehicle, the normal procedure for static balancing as described under "Wheel Balance" in the Wheels, Bearings and Tires Section of this manual should be followed. Dynamic balancing of front wheels can be accomplished by the normal procedure when wheels are removed from the vehicle, but Manufacturer's recommendations should be followed closely when attempting to balance wheels while on the vehicle.

DISC BRAKE (FLOATING CALIPER)

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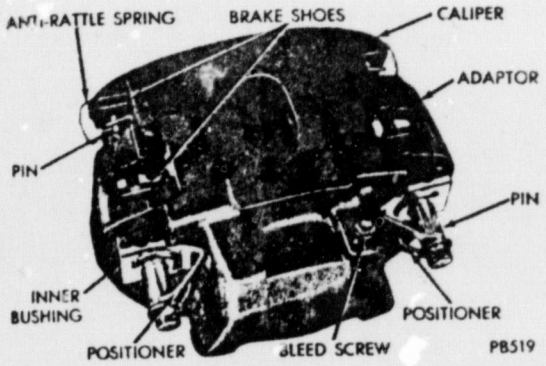

Fig. 1 - Floating Caliper Assembly (Single Piston)

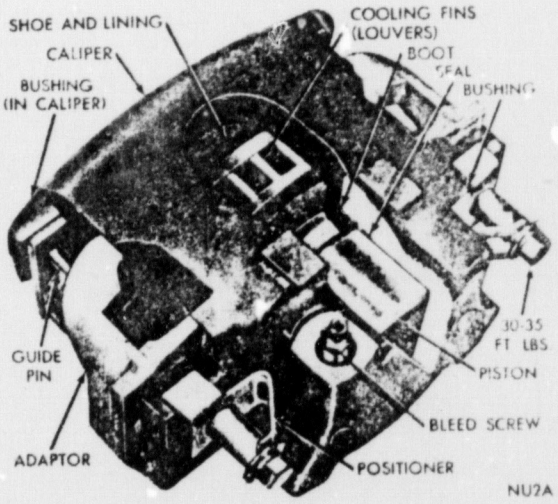

Fig. 2 - Floating Caliper Assembly (Sectional)

GENERAL INFORMATION

The single piston, floating caliper disc brake assembly (Figs. 1 and 4), consists of the hub and disc assembly, the caliper, shoes and linings, splash shield and adaptor.

The cast iron braking disc has cooling fins (or louvres) that are cast integrally between the two machined braking surfaces (Fig. 2). When the wheel is in motion, the rotation of the disc cooling fins supplies air circulation between the braking surfaces for efficient cooling of the disc and prolonged lining life. The braking disc is protected from road splash (inboard side) by a shield bolted to the steering knuckle and by the wheel and tire on the outboard side.

The single piston caliper assembly floats through four rubber bushings on two steel guide pins threaded into the adaptor. Two of the bushings are inserted in the outboard portion of the caliper and two on the inboard side (Fig. 3). Four machined abutments on the adaptor, position and align the caliper, fore and aft. Two positioners installed over the guide pins, control the movement of the caliper along with the piston seal, and assists in maintaining proper shoe clearance and are also required to hold the inner bushing in place.

The guide pins are also used to radially locate and restrain both shoes, while all of the braking force is taken by the caliper on the outboard shoe and machined lug (Fig. 9) on the adapter for the inboard shoe.

The caliper is a one piece casting with the inboard side containing the single piston cylinder bore. The steel piston is 2-3/4 inches in diameter and is nickle and chrome plated for anti-corrosion and long wear. The square cut rubber piston seal is located in a machined groove in the cylinder bore and provides a hydraulic seal between the piston and the cylinder wall (Fig. 4). The adaptor is mounted to the steering knuckle by two special nylock bolts (Fig. 5).

A moulded rubber dust boot installed in a groove in the cylinder bore and piston, keeps contamination from the cylinder wall and piston. The boot has a

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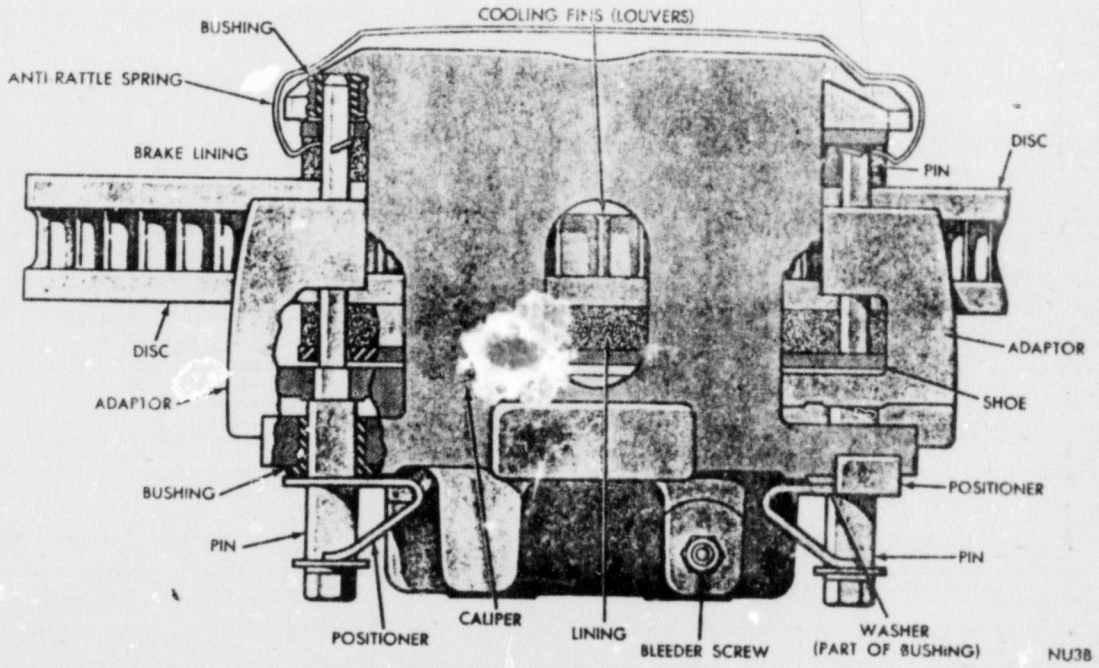

Fig. 3 - Floating Caliper Assembly (Sectional)

wiping lip (Fig. 6) that prevents contamination in the bore area.

As the brake pedal is depressed, hydraulic pressure is applied against the piston. This force is transmitted to the inboard brake shoe and lining and the inboard braking surface of the disc. As force increases against the disc from the inner lining, the caliper assembly moves inboard, sliding on the guide pins, thus providing a clamping force on the disc.

When the brake pressure is released, the piston seal (distorted by applied pressure) returns to its normal position, pulling the piston back to released position, while the two positioners force the caliper outboard to create a slight running clearance between outer shoe and the disc.

Automatic adjustment is obtained by outward relocation of the piston as the inboard lining wears and the inward movement of the caliper as the outboard lining wears, thus maintaining correct adjustment at all times.

METERING/PROPORTIONING VALVES

All floating caliper disc brake equipped vehicles are equipped with a pressure metering valve or combination pressure metering/proportioning valve (see "Hydraulic System Control Valves", this Group) the use of the valves will better match the front disc brakes with the rear drum brakes on the vehicle. This results in improved braking and steering control.

ROUTINE MAINTENANCE—30,000 Miles

Check Brake Lines, Hoses and Linings

Raise all four wheels. Remove front wheel and tire assemblies and inspect the braking disc, linings and caliper. Inspect brake flexible hose and tubing according to procedure outlined in paragraph entitled "Brake Hose and Tubing" (The wheel bearings should be inspected at this time and repacked if necessary). **The caliper assembly must be removed in order to inspect the inner wheel bearings.** (Refer to "Brake Shoe Removal" paragraph).

Do not get oil or grease on the braking disc or linings. If the linings (pads) are worn to within .030 inch of the shoe, replace both sets of shoe and lining assemblies, (inboard and outboard) on the front wheels. It is necessary that both front wheel sets be replaced whenever a respective shoe and lining is worn beyond specifications or damaged.

Check all brake tube connections for possible leaks. Install new flexible hoses as required.

Check adapter plate to knuckle bolts for specified torque (75 to 100 Foot Pounds).

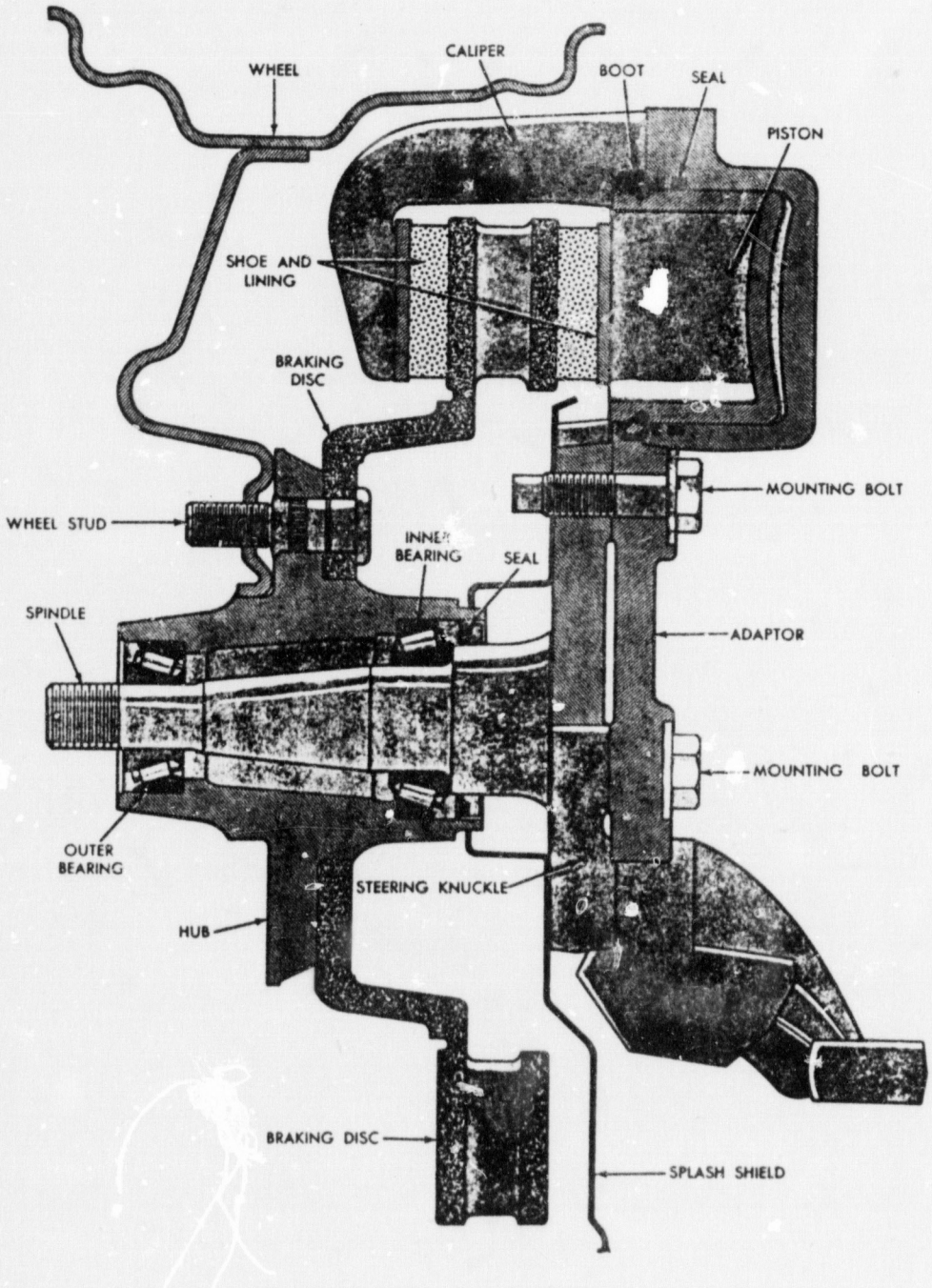

Fig. 4 - Disc Brake Assembly (Sectional)

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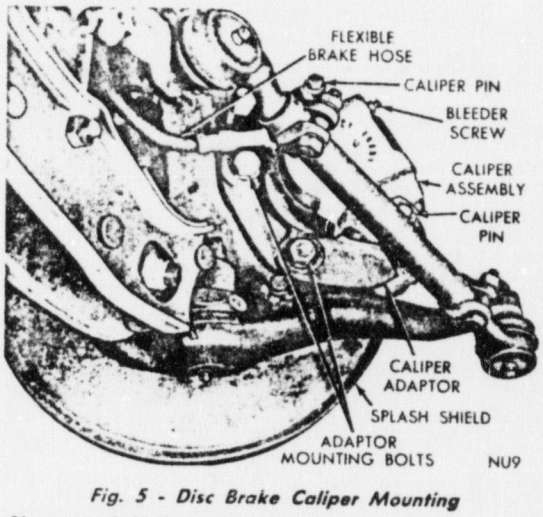

Fig. 5 - Disc Brake Caliper Mounting

Shoe and Lining Wear

If a visual inspection does not adequately determine the condition of the lining, a physical check will be necessary. To check the amount of lining wear, remove the wheel and tire assemblies, and the calipers. Remove the shoe and lining assemblies. (See "Brake Shoe Removal" paragraph). Three (3) thickness measurements with a micrometer should be taken across the center of the shoe and lining; one reading at each end and one reading in the center. When an assembly has been worn to a thickness of .230 inch, it should be replaced. If a shoe and lining does not require replacement, reinstall, making sure each shoe and positioner is returned to their original positions. (See "Brake Shoe Installation" paragraph). It is normal for the inboard lining to show slightly more wear than the outboard.

Brake Roughness

The most common cause of brake roughness (or chatter) with disc brakes are excessive variation in disc thickness and/or excessive disc face runout. These can be easily checked with a dial indicator and a 2 in. micrometer (vernier type preferred). If either of the measurements are out of specification, the disc must be refinished or replaced. Refer to "Refinishing (Refacing) Braking Disc" paragraph.

Other less prevalent causes of roughness can be the use of some types of non-standard lining and extreme abrasion of the disc faces. Also, vehicles which stand unused for periods of time in areas of high humidity or salt air may incur rust on the disc which could cause a temporary brake surge and roughness. Normally, however, this condition should correct itself after a short period of usage. If rust is severe enough roughness will not clear up and the disc must be resurfaced or replaced.

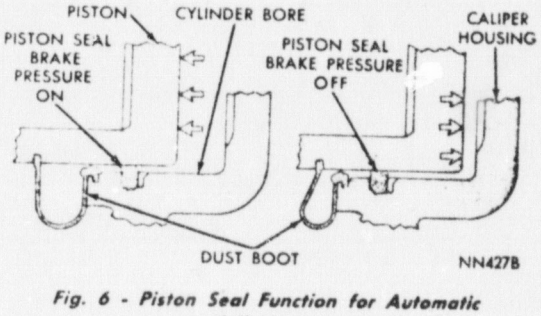

Fig. 6 - Piston Seal Function for Automatic Adjustment

BRAKE HOSE AND TUBING

Installation of Brake Hose

The flexible hydraulic brake hose should **always** be installed on the vehicle by first tightening the male end of the hose into caliper, wheel cylinder, or rear axle housing tee. The hose should then be attached to the hose bracket in a manner to give minimum twist. (15 degree twist is the maximum recommended). Excessive twist can result in hose interference problems with possible hydraulic system failure.

Inspection of Brake Hose and Tubing

Inspection of brake hose and tubing should be included in all brake service operations and every 6 months or 6,000 miles (every 3 months or 4,000 miles for vehicles used in fleet service; Police Taxi, etc.). The hoses should be checked for:

(1) Correct length, severe surface cracking, pulling scuffing or worn spots. **(Should the fabric casing of the hose be exposed by cracks or abrasions in the rubber hose cover, the hose should be replaced).** Eventual deterioration of the hose can take place with possible burst failure.

(2) Faulty installation to cause twisting, wheel, tire or chassis interference.

Always use factory recommended hose to insure quality, correct length and superior fatigue life. Care should be taken to make sure that the tube and hose mating surfaces are clean and free from nicks and burrs. New copper seal washers should be used and the tube nuts and connections should be properly made and tightened. Double wall steel tubing should always be used to insure superior fatigue life. Care should be taken when replacing brake tubing, to use the proper bending and flaring tools and to avoid routing the tubes against sharp edges, moving components or in hot areas. All tubes should be properly attached with recommended retaining clips.

DISC BRAKE SERVICE PRECAUTIONS

(1) Grease or any other foreign material must be kept off the caliper assembly, surfaces of the braking disc and external surfaces of the hub, during

service procedures. Handling the braking disc and caliper should be done in such a way as to avoid deformation of the disc and scratching or nicking the brake linings (pads).

(2) If inspection reveals that the square sectioned caliper piston seal is worn or damaged, it should be replaced immediately.

(3) During removal and installation of a wheel and tire assembly, use care not to strike the caliper.

(4) The front wheel bearing end play is important and must be within specifications.

(5) Be sure vehicle is centered on the hoist before servicing any of the front end components to avoid bending or damaging disc splash shield on full right or left hand turns.

(6) Before vehicle is moved after any brake service work, **be sure and obtain a firm brake pedal** by using proper bleeding procedures: see "Hydraulic System Control Valves", this Group.

(7) Dragging the brakes (common result of left foot application) should be avoided during vehicle operation.

(8) The wheel, tire, hub and disc assembly **cannot** be removed as an assembly. The caliper assembly must be removed before removal of the hub and disc assembly.

(9) As lining wears, reservoir level will go down. If fluid has been added between relines, then reservoir overflow may occur when the piston is pushed back into the new lining position. Overflowing can be avoided in this case by removal of a small amount of fluid before overflow occurs.

SERVICE DIAGNOSIS

Condition	Possible Cause	Correction
EXCESSIVE PEDAL TRAVEL	(a) Air, leak, or insufficient fluid in system or caliper.	(a) Check system for leaks and bleed.
	(b) Warped or excessively tapered shoe and lining assembly.	(b) Install new shoe and linings.
	(c) Excessive disc runout.	(c) Check disc for runout with dial indicator. Install new or refinished disc.
	(d) Rear brake adjustment required.	(d) Check and adjust rear brakes.
	(e) Loose wheel bearing adjustment.	(e) Readjust wheel bearing to specified torque.
	(f) Damaged caliper piston seal.	(f) Install new piston seal.
	(g) Improper brake fluid (boil).	(g) Drain and install correct fluid.
	(h) Power brake malfunction.	(h) Replace.
BRAKE ROUGHNESS OR CHATTER (PEDAL PUMPING)	(a) Excessive thickness variation of braking disc.	(a) Check disc for thickness variation using a micrometer.
	(b) Excessive lateral runout of braking disc.	(b) Check disc for lateral runout with dial indicator. Install new or refinished disc.
	(c) Rear brake drums out-of-round.	(c) Reface rear drums and check for out-of-round.
	(d) Excessive front bearing clearance.	(d) Readjust wheel bearings to specified torque.
EXCESSIVE PEDAL EFFORT	(a) Brake fluid, oil or grease on linings.	(a) Install new shoe linings as required.
	(b) Incorrect lining.	(b) Remove lining and install correct lining.
	(c) Frozen or seized pistons.	(c) Disassemble caliper and free up pistons.
	(d) Power brake malfunction.	(d) Replace.
PULL	(a) Brake fluid, oil or grease on linings.	(a) Install new shoe and linings.
	(b) Unmatched linings.	(b) Install correct lining.
	(c) Distorted brake shoes.	(c) Install new brake shoes.
	(d) Frozen or seized pistons.	(d) Disassemble caliper and free up pistons.
	(e) Incorrect tire pressure.	(e) Inflate tires to recommended pressures.
	(f) Front end out of alignment.	(f) Align front end and check.
	(g) Broken rear spring.	(g) Install new rear spring.
	(h) Rear brake pistons sticking.	(h) Free up rear brake pistons.
	(i) Restricted hose or line.	(i) Check hoses and lines and correct as necessary.

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SERVICE DIAGNOSIS

Condition	Possible Cause	Correction
	(j) Caliper not in proper alignment to braking disc.	(j) Remove caliper and reinstall. Check alignment.
NOISE Groan—Brake noise emanating when slowly releasing brakes (creep-groan).	(a) Not detrimental to function of disc brakes—no corrective action required. (Indicate to operator this noise may be eliminated by slightly increasing or decreasing brake pedal efforts.)	
RATTLE—Brake noise or rattle emanating at low speeds on rough roads, (front wheels only).	(a) Shoe anti-rattle spring missing or not properly positioned.	(a) Install new anti-rattle spring or position properly.
	(b) Excessive clearance between shoe and caliper.	(b) Install new shoe and lining assemblies.
SCRAPING—	(a) Mounting bolts too long.	(a) Install mounting bolts of correct length.
	(b) Loose wheel bearings.	(b) Readjust wheel bearings to correct specifications.
FRONT BRAKES HEAT UP DURING DRIVING AND FAIL TO RELEASE	(a) Operator riding brake pedal.	(a) Instruct owner how to drive with disc brakes.
	(b) Stop light switch improperly adjusted.	(b) Adjust stop light to allow full return of pedal.
	(c) Sticking pedal linkage.	(c) Free up sticking pedal linkage.
	(d) Frozen or seized piston.	(d) Disassemble caliper and free up piston.
	(e) Residual pressure valve in master cylinder.	(e) Remove valve.
	(f) Power brake malfunction.	(f) Replace.
LEAKY WHEEL CYLINDER	(a) Damaged or worn caliper piston seal.	(a) Disassembly caliper and install new seal.
	(b) Scores or corrosion on surface of cylinder bore.	(b) Disassemble caliper and hone cylinder bore. Install new seal.
GRABBING OR UNEVEN BRAKING ACTION	(a) Causes listed under "Pull".	(a) Corrections listed under "Pull".
	(b) Power brake malfunction.	(b) Replace.
BRAKE PEDAL CAN BE DEPRESSED WITHOUT BRAKING EFFECT	(a) Air in hydraulic system or improper bleeding procedure.	(a) Bleed system.
	(b) Leak past primary cup in master cylinder.	(b) Recondition master cylinder.
	(c) Leak in system.	(c) Check for leak and repair as required.
	(d) Rear brakes out of adjustment.	(d) Adjust rear brakes.
	(e) Bleeder screw open.	(e) Close bleeder screw and bleed entire system.

SERVICE PROCEDURES

BRAKE SHOE REMOVAL

(1) Raise vehicle on a hoist or jackstands.

(2) Remove front wheel covers, and wheel and tire assemblies.

(3) Remove caliper guide pins, positioners that attach caliper to adaptor and anti-rattle spring.

(4) Remove caliper from disc by slowly sliding caliper assembly out and away from braking disc (Fig. 7). Support caliper firmly so as not to damage

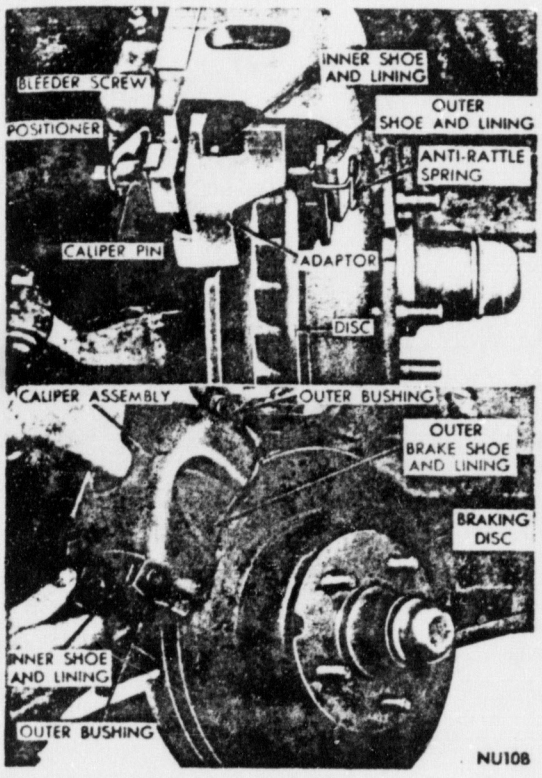

Fig. 7 - Removing or Installing Caliper

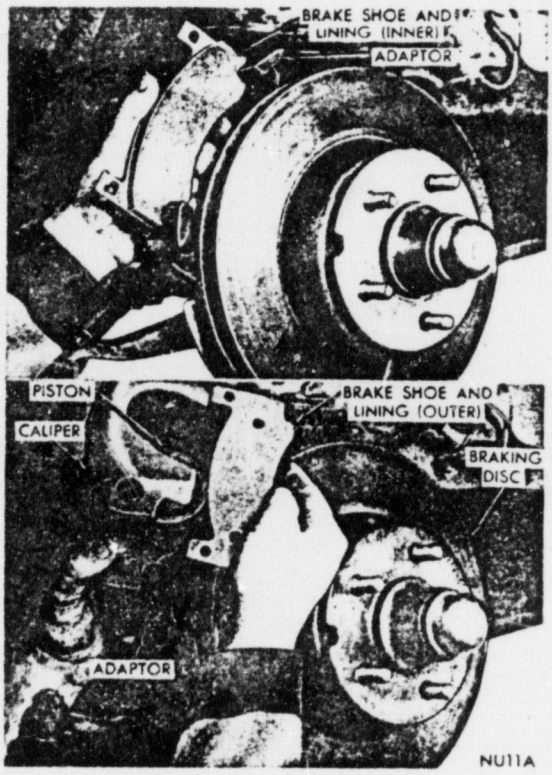

Fig. 8 - Removing or Installing Brake Shoes and Lining

flexible brake hose.

(5) Slide outboard shoe and lining assembly out of caliper. Slide inboard shoe and lining assembly out of adaptor (Fig. 8).

(6) Remove outer bushings from caliper by pressing out of bore (Fig. 9 and 13) using a suitable tool. **Discard bushings.**

(7) Slide inner bushings (flanged) off guide pins and discard. Remove positioners from guide pins and discard.

CLEANING AND INSPECTION

Check for piston seal leaks (evident by brake fluid in and around boot area at inboard lining) and for any ruptures of piston dust boot. If boot is damaged, or fluid is evident, it will be necessary to disassemble caliper assembly and install a new seal, boot, (and piston if damaged or corroded.) (Refer to "Disassembling Caliper Assembly" paragraph). Check the mating surfaces of the abutments on the caliper and adaptor. If corroded or rusty, clean surfaces with wire brush. Inspect braking surfaces of disc.

BRAKE SHOE INSTALLATION

When installing new shoe and lining assemblies, it will be necessary to also install new POSITIONERS, INNER BUSHINGS AND OUTER BUSHINGS.

(1) Slowly and carefully push piston back into bore until it is bottomed. Watch for possible reservoir overflow. See Step 9 of "Disc Brake Service Precautions".

(2) Install new inner guide pin bushings in caliper with flanged end on inboard side (Fig. 3). Compress flanges of outboard bushing in fingers and work into position in hole from the outboard side of caliper (Fig. 17).

(3) Slide new shoe and lining assemblies into position in adaptor and caliper (Fig. 8), being sure that metal portion of shoe is fully in recess of caliper and adaptor.

(4) Holding outboard lining in position, carefully slide caliper down into position in adaptor and over disc. Align guide pin holes of adapter, inboard and outboard shoes. (Fig. 3).

(5) Install new positioners over guide pins with open ends toward outside, **and with stamped arrows pointing upwards** (Fig. 1). Install assembled guide pins through bushing, caliper, adaptor, inboard and outboard shoes, into outer bushings in

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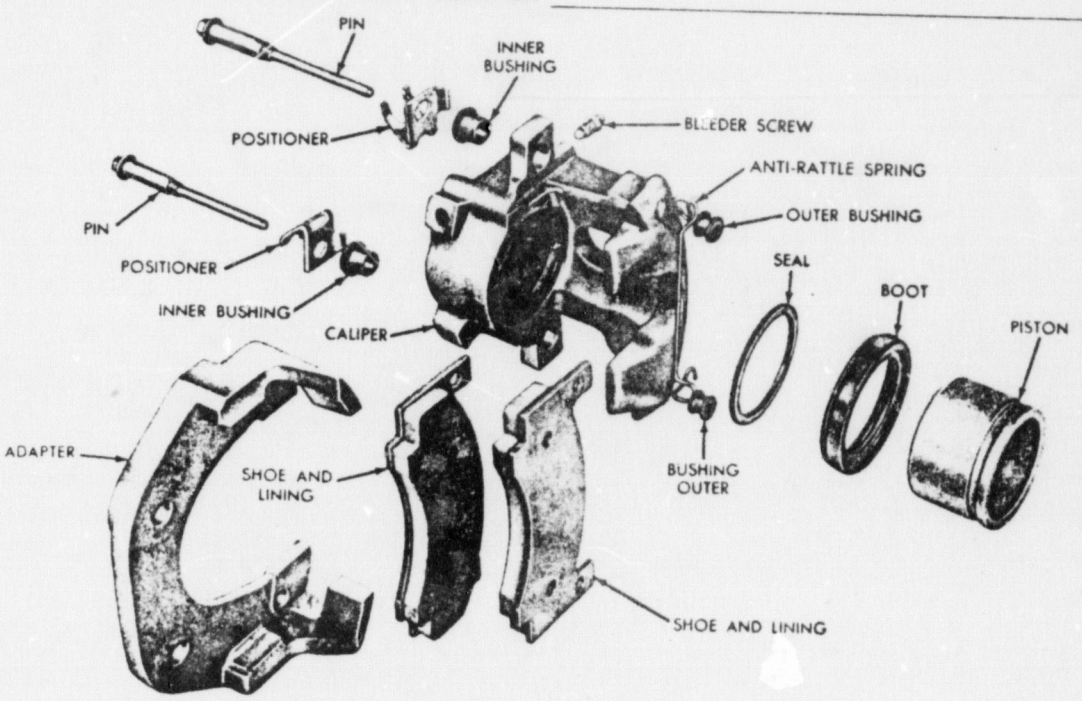

Fig. 9 - Caliper Assembly (Exploded View)

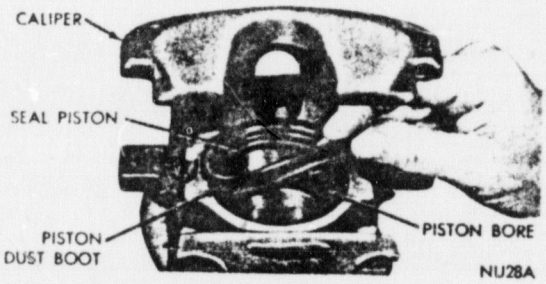

Fig. 10 - Removing or Installing Piston Dust Boot

caliper and anti-rattle spring.

(6) Press **IN** on end of guide pins and thread pin into adaptor, **USING EXTREME CARE SO AS NOT TO CROSS THREADS**. Tighten from 25 to 35 foot-pounds. Be sure tabs of positioners are over machined surfaces of caliper (Fig. 1).

(7) Pump brake pedal several times until a firm pedal has been obtained.

(8) Check and refill master cylinder reservoirs (if necessary) with approved brake fluid as required. (It should not be necessary to bleed the system after shoe and lining removal and installation). However, if a firm pedal cannot be obtained bleed the brake system as described in "Bleeding Brake System" paragraph. **It may have been necessary to remove fluid to put in new linings as fluid is pushed back into master cylinder.**

(9) Install wheel and tire assemblies and wheel covers.

(10) Remove jackstands or lower hoist.

REMOVING CALIPER FROM VEHICLE

It will be necessary to remove the caliper to install a new piston seal and boot.

(1) Raise vehicle on a hoist or jackstands.

(2) Remove front wheel covers and wheel and tire assemblies.

(3) Disconnect front brake flexible hose from tube at frame mounting bracket. **(If pistons are to be removed from caliper leave flexible brake line connected to tube at frame mounting bracket. See "Disassembling Caliper".)** Plug brake tube to prevent loss of fluid, or prop brake pedal to any position below the first inch of travel. Disconnect hose from caliper.

(4) Remove guide pins and positioners that attach caliper to adaptor. Carefully slide caliper out and away from disc and adaptor, while holding outboard shoe and lining assembly. Remove inboard shoe and lining from adaptor.

DISASSEMBLING CALIPER

(1) Raise vehicle. Remove wheel and tire assemblies.

(2) Remove guide pins and positioners that attach

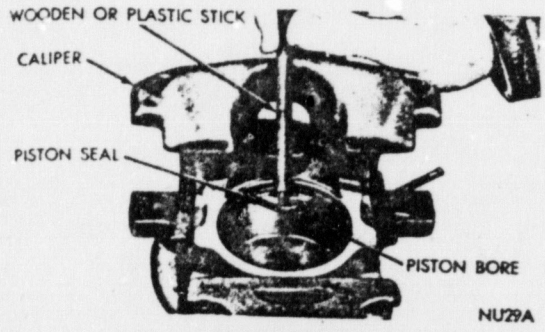

Fig. 11 - Removing Piston Seal

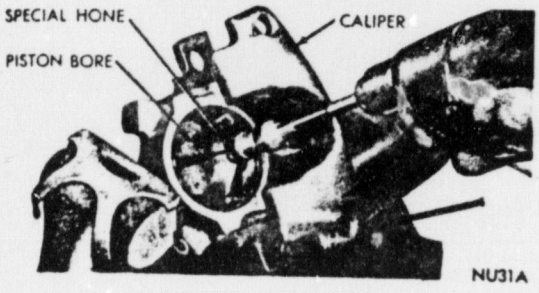

Fig. 13 - Honing Piston Bore

caliper to adaptor. Carefully slide caliper out and away from disc and adaptor, while holding outboard shoe and lining assembly. Remove inboard shoe and lining assembly.

(3) Support caliper and remove dust boot (Fig. 10).

(4) To remove piston support caliper assembly on upper control arms on shop towels to absorb any hydraulic fluid loss. **Carefully** depress brake pedal to hydraulically push piston out of bore (brake pedal will fall away when piston has passed bore opening) prop brake pedal to any position below the first inch of pedal travel to prevent loss of brake fluid. (If both front caliper pistons are to be removed, disconnect flexible brake line at frame bracket after removing first piston. Plug brake tube to remove piston from opposite caliper.)

CAUTION: UNDER NO CONDITION SHOULD AIR PRESSURE BE USED TO REMOVE PISTON FROM BORE! PERSONAL INJURY COULD RESULT FROM SUCH PRACTICE.

(5) Disconnect brake flexible hose from tube at frame mounting bracket.

(6) Mount caliper assembly in a vise equipped with protector jaws. **Caution: Excessive vise pressure will cause bore distortion and binding of piston.**

(7) Using a small, pointed, wooden or plastic stick, work piston seal out of its groove in piston bore (Fig. 11). Discard old seal. **Do not use a screwdriver or other metal tool for this operation,**

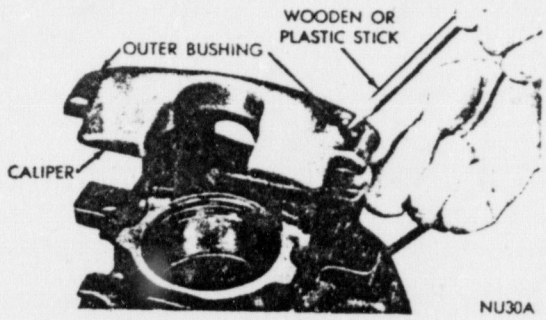

Fig. 12 - Removing Outer Bushings

because of possibility of scratching piston bore or burring edges of seal groove.

(8) Remove outer bushings from caliper by pressing out of bore, (Fig. 12) using a suitable tool. Discard bushings.

(9) Remove inner bushing and discard. Remove bleeder screw.

CLEANING AND INSPECTION

Clean all parts using alcohol or a suitable solvent and blow dry, using compressed air. Blow out all drilled passages and bores. (Whenever a caliper has been disassembled, and a new boot and seal must be installed at reassembly). Inspect the piston bore for scoring or pitting. Install a new piston if it is pitted, scored or the plating is severely worn. Bores that show light scratches or corrosion, can usually be cleared with crocus cloth. However, bores that have deep scratches or scoring should be honed, using Tool C-4095, providing the diameter of the bore is not increased more than .002 inch. If the bore does not clean up within this specification, a new caliper housing should be installed. Black stains on the piston are caused by the piston seal and will do no harm.

When using Hone C-4095, coat the stones and bore with brake fluid. After honing the bore, carefully clean the seal and boot grooves with a stiff non-metallic rotary brush (Fig. 13).

Use extreme care in cleaning the caliper after honing. Remove all dirt and grit by flushing the caliper with brake fluid; wipe dry with a clean, lintless cloth and then clean a second time in the same manner or until clean cloth shows no signs of discoloration.

ASSEMBLING CALIPER

(1) Clamp caliper in vise (with protector jaws). **Caution: Excessive vise pressure will cause bore distortion and binding of piston.**

(2) Dip new piston seal in lubricant (supplied with kit) Ucon LB1145Y24 (or equivalent) and install in groove in bore. Seal should be positioned at one area in groove and gently worked around the

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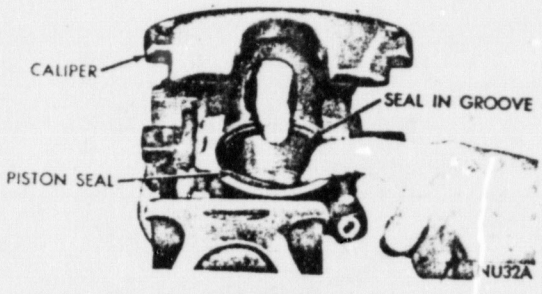

Fig. 14 - Installing Piston Seal

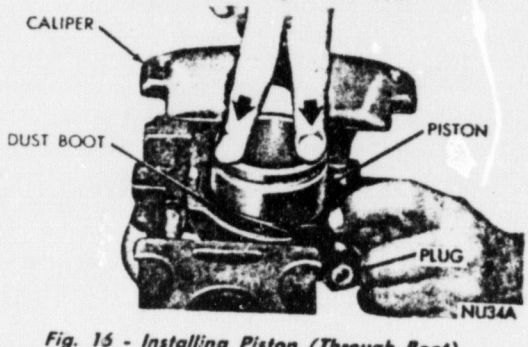

Fig. 16 - Installing Piston (Through Boot)

groove, using clean fingers, until properly seated. **NEVER USE AN OLD PISTON SEAL.** (Be sure seal is not twisted or rolled) (Fig. 14).

(3) Coat new piston boot with lubricant (as specified above) leaving a generous amount of lubricant inside of boot. Install in caliper by working into outer groove, using fingers only. (Boot will seem larger than diameter of groove, but will snap into place when properly positioned in groove (Fig. 15). Using a forefinger, slide around inside of boot to be sure it is seated, or correctly installed.

(4) Plug high pressure inlet to caliper and bleeder screw hole, then coat piston with a generous amount of lubricant (as specified above). With fingers spreading boot, work piston into boot and press down on piston. (The entrapped air below piston will force boot around piston and into its groove as piston is depressed). (Fig. 16). Remove plug, then carefully push piston down the bore until bottomed. **Caution: Force must be applied uniformly to avoid cocking.**

(5) Install new inner guide pin bushings in caliper with flanged end on inboard side (Fig. 3). Compress flanges of outboard bushing in with fingers and work into position in hole from the outboard side of the caliper (Fig. 17). Press **IN** on bushing, using finger tips or small plastic stick (Fig. 17) until seated. Be sure flanges extend over caliper casting evenly on both sides. Install bleeder screw.

Before installing caliper assembly on vehicle, inspect braking disc. Conditions as described in "Checking Braking Disc for Runout and Thickness" paragraph.

Fig. 15 - Installing Piston Dust Boot

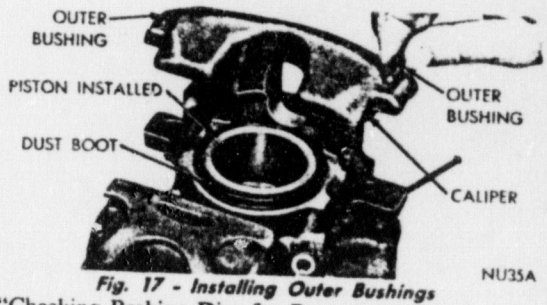

Fig. 17 - Installing Outer Bushings

INSTALLING CALIPER

(1) Examine lining for wear damage, or fluid contamination if its condition is found satisfactory it may be reused. If not usable both front brakes must be relined with new. If old lining is to be reused, be sure linings and positioners are installed in their original position.

(2) Connect flexible brake hose to caliper, using a new gasket. Torque hose fitting to 25 foot-pounds. Then attach brake hose to frame bracket.

CAUTION: The flexible brake hose should **always** be installed in the vehicle by first tightening the male end of the hose in the wheel cylinder or rear axle housing tee. The hose should then be attached to the hose bracket in a manner to give minimum twist (15 degree twist is the maximum recommended). Excessive twist can result in hose interference problems with possible hydraulic system failure.

(3) Install new inboard shoe and lining into adaptor (Fig. 8). Holding outboard shoe and lining in position in caliper, carefully slide caliper down into position in adaptor and over disc. Align pin holes of caliper, adaptor and inboard and outboard shoes and anti-rattle spring.

(4) Install positioners over guide pins with open ends toward outside and arrows pointing upwards (Fig. 1) Install assembled guide pins through bushing, caliper, adaptor, inboard and outboard shoes and into outer bushings in caliper and anti-rattle spring.

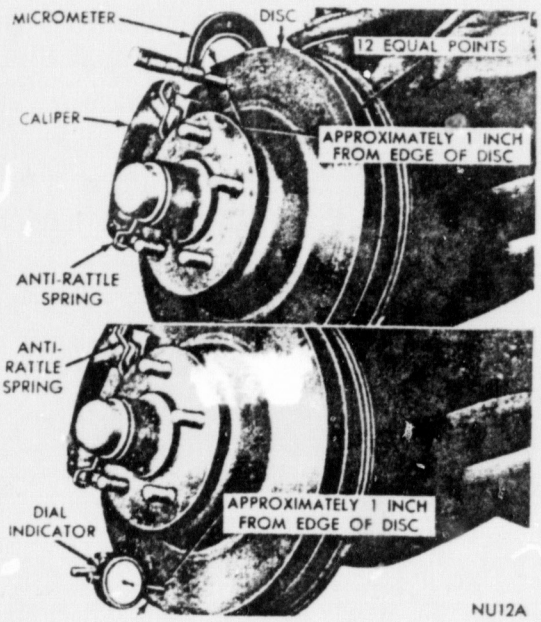

Fig. 18 - Checking Braking Disc Run-out and Thickness

(5) Press **IN ON END GUIDE PINS AND THREAD PINS INTO ADAPTOR. USING EXTREME CARE SO AS NOT TO CROSS THREADS**. Tighten from 25 to 35 foot-pounds. (Be sure tabs of positioners are over machined surfaces of caliper) (Fig. 1).

(6) Remove plug from brake tube and install flexible brake hose. Tighten securely. Avoid twisting hose.

(7) With bleeder screw open, allow caliper to "gravity" fill with brake fluid, then close bleeder screw. (Be sure all air bubbles have escaped; replenish brake fluid in master cylinder. Bleed brakes as described under "Bleeding Brakes" paragraph).

(8) **Pump brake pedal several times until a firm pedal has been obtained.**

(9) After bleeding caliper, check for fluid tightness under maximum pedal pressures. (Recheck master cylinder reservoir level).

(10) Install wheel and tire assembly. Tighten stud nuts using a star pattern (skip every other nut going around) until all 5 are torqued to 65 foot-pounds. **This is important.** Install wheel cover.

(11) Remove jackstands or lower hoist.

(12) **Road test vehicle and make several stops to wear off any foreign material on the brakes and to seat the linings. The vehicle may pull to one side or the other if this is not done.**

CHECKING BRAKING DISC FOR RUNOUT AND THICKNESS

(1) Mount dial indicator C-3339 on steering arm with plunger contacting disc approximately one (1) inch from edge of disc (Fig. 18).

(2) With wheel bearings adjusted to zero end play, check lateral runout. (Both sides of disc). Runout should not exceed .0025 inch. If runout is in excess of specification, install a new disc and hub assembly or reface disc, being careful to remove as little as possible from each side of disc. Remove equal amounts from each side of disc. Do not reduce thickness below minimum thickness shown in refinishing section below. Be sure and readjust wheel bearings after check.

(3) Thickness variation of disc should be made in conjunction with runout. Measure thickness of disc at twelve (12) equal points with a micrometer at a radius approximately one (1) inch from edge of disc. If thickness measurements vary by more than .0005 inch, disc should be removed and resurfaced or a new disc and hub assembly installed (Fig. 18).

(4) Light scoring and/or wear is acceptable if heavy scoring or warping is evident, the disc must be refinished or replaced (See Refinishing (Refacing) Braking Disc). If cracks are evident the hub and disc assembly must be replaced.

REMOVING BRAKING DISC AND HUB

(1) Raise vehicle on hoist or jackstands. Remove wheel cover and wheel and tire assembly.

(2) Remove caliper assembly, as described under "Removing Caliper" paragraph, (but do not disconnect brake line). Suspend caliper from wire hook or loop to avoid strain on flexible hose.

(3) Remove grease cap, cotter pin, nut lock, nut, thrust washer and outer wheel bearing.

(4) Pull disc and hub off wheel spindle.

INSTALLING BRAKING DISC AND HUB

(1) Slide brake disc and hub assembly on spindle.

(2) Install outer bearing, thrust washer and nut.

(3) Tighten wheel bearing adjusting nut to 90 inch-pounds while rotating disc and hub. Recheck disc runout as described previously.

(4) Position lock nut on nut with one pair of slots in line with cotter pin hole.

(5) Back off adjusting nut and lock assembly one slot.

(6) Clean grease cap, coating inside with wheel grease (do not fill cap) and install cap. Clean both sides of braking disc with alcohol or suitable solvent.

(7) Install caliper assembly, as described in "Installing Caliper" paragraph.

REFINISHING (REFACING) BRAKING DISC

Before refinishing or refacing a braking disc, the disc should be checked and inspected for the following conditions:

(1) Scoring, rust, impregnation of lining material

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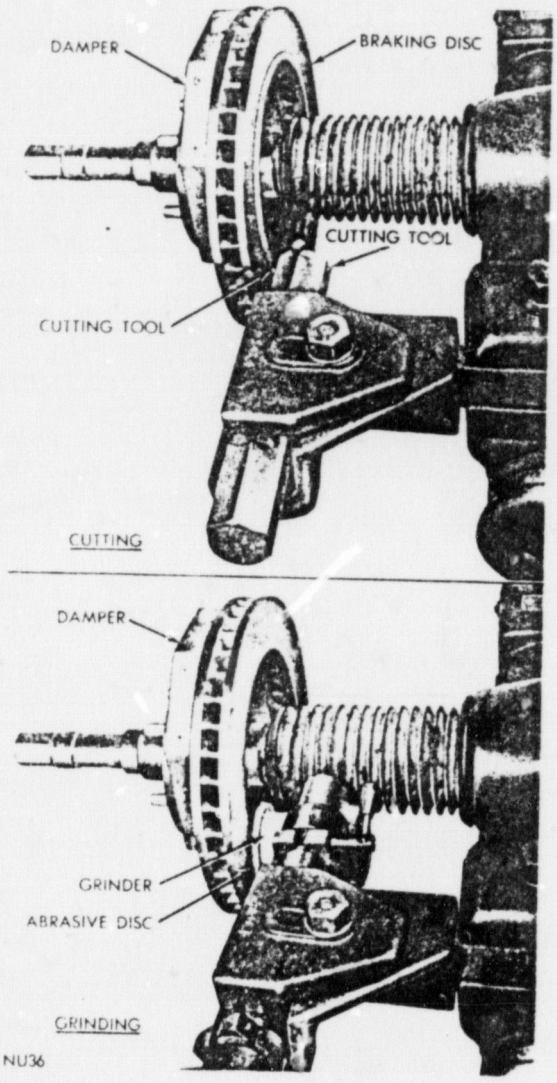

Fig. 19 - Refacing Braking Disc

and worn ridges.

(2) Runout or wobble.

(3) Thickness variation (Parallelism).

(4) Dishing or distortion (Flatness).

If a vehicle has not been driven for a period of time, the discs will rust in the area not covered by the lining and cause noise and chatter, excessive wear and scoring of the discs and lining. Wear ridges on the discs can cause temporary improper lining contact if ridges are not removed before installation of new lining (pads).

Lining deposit on the disc, may cause erratic friction characteristics if new lining is installed without resurfacing or cleaning the disc.

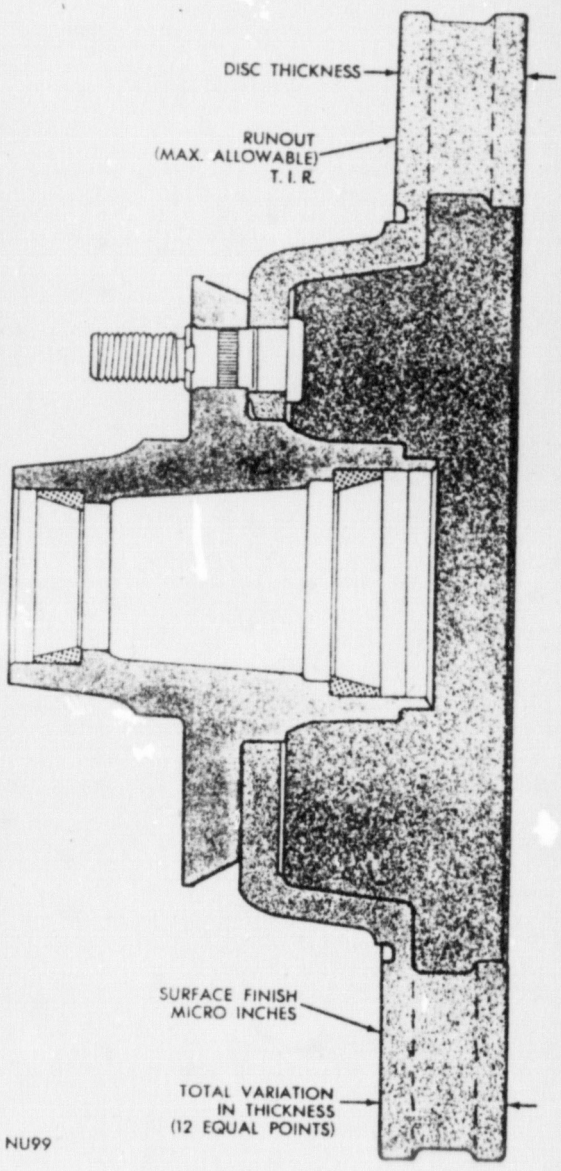

Fig. 20 - Disc Specifications

Excessive runout or wobble in a disc can increase pedal travel due to piston knockback and increase seal bushing wear due to necessity of caliper to follow the disc wobble.

Thickness variation in a disc can also result in pedal pulsation, chatter and surge due to variation in brake output when disc section is uneven.

Dishing or distortion can be caused by extreme heat and abuse of the brakes.

Resurfacing Braking Disc

This operation can be used when the disc surface is rusty or has lining deposits. A sanding disc attachment will remove surface contamination without removing much material. It will generally follow variations in thickness which are in the disc.

Refacing Braking Disc

If scoring is deep, runout or thickness variation is beyond limits, or other distortion is apparent, the disc should be refaced on a brake lathe equipped for disc machining (Fig. 19). After machining a disc, a grinder may be used to remove tool marks.

A new disc and hub assembly should be installed if the old one cannot be refaced to bring it within specifications without removing an excessive amount of material. Do not remove more than .050 inch per disc. Brake operation may be affected if an excess of material is removed.

Both sides of the braking surface should be machined or ground an equal amount when servicing since small variations in resurfacing machines may cause the newly finished surface to be out of parallel with the opposite unfinished side resulting in a thickness variation beyond acceptable limits. Disc brakes are very sensitive to thickness variation.

The following chart and (Fig. 20) shows the location and tolerances of required specifications when servicing the braking disc:

NOTE: All rotors will show markings of minimum allowable thickness cast on the un-machined surface of the rotor.

	Thickness	Minimum Thickness	Thickness Variation	Runout	Micro Finish
Braking Disc (Floating Caliper)					
All Except, Satellite and Barracuda	1.250-1.240	1.180	.0005	.0025	15-80
Satellite and Barracuda	1.000-1.010	0.940	.0005	.0025	15-80

CAUTION:
When refacing a braking disc (Fig. 19), the manufacturers of the refacing equipment instructions should be followed closely, and the correct brake disc mounting adaptors must be used to obtain the required specifications.

BLEEDING DISC BRAKE

The disc brake hydraulic system can be bled manually or with pressure bleeding equipment. Refer to "Hydraulic System Control Valves" section for lockout during bleeding procedure. On disc brake equipped vehicles, the brake pedal will require more pumping, and frequent checking of the fluid level in the master cylinder during the bleeding operation. **Never use brake fluid that has been drained from the hydraulic system, when bleeding the brakes.**

On vehicles equipped with disc brakes, be sure that the disc brake piston is returned to a normal position and that the shoe and lining assemblies are properly seated.

Before driving the vehicle, check the operation of the brakes to be sure that a firm pedal has been obtained.

(1) Raise vehicle using a hoist or jackstands.

(2) Bleed brakes in usual manner, starting with right rear, then proceeding to left rear, right front and left front in order.

After bleeding the brakes, proceed as follows:

(1) Remove jackstands or lower hoist.

(2) Test drive vehicle to be sure brakes are operating correctly and that pedal is solid.

SURE BRAKE

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GENERAL INFORMATION

The Sure Brake System is designed to prevent any wheel from locking up during brake applications above a speed of approximately 5 MPH. The system reduces the skid potential of a locked wheel and still maintains the brake pressure for maximum stopping effort. The end result is to improve the directional control and steerability of the vehicle, and in many cases to reduce the distance required to bring the vehicle to a stop.

The major components of the Sure Brake System are shown in Figures 14, 15 and 16. These components include:

(1) A mechanically driven speed sensor at each wheel.

(2) A logic controller (LC) located inside the right rear quarter panel.

(3) Three pressure modulators; one modulator is under each front fender ahead of the wheels and one is next to the radiator on the right side of the engine compartment.

Speed Sensors

The speed sensors are mechanically driven electromagnetic devices. Speed sensors used on the rear wheels are a friction drive type as shown in Figure 13.

The rear wheel, friction type speed sensors consist of a stationary permanent magnet and coil in a case and a tone wheel attached to a mounting bracket. A part of the mounting bracket forms a spring to hold the shaft of the tone wheel in contact with a band that is pressed into a drive ring. The drive ring is secured between the axle flange and the drum (by the wheel studs), and rotates with the rear wheel. The clearance between the magnet and the tone wheel teeth is not adjustable.

The front wheel speed sensors are a frictionless drive type as shown in Figures 11 and 12. These sensors also include a stationary permanent magnet and coil in a case which is attached to a mounting bracket. Instead of the small friction driven tone wheel used on the rear sensors, however, a large tone wheel is pressed on the hub of the disc brake rotor. The tone wheel rotates with the front wheel. The clearance between the magnet and tone wheel teeth is adjustable (Fig. 11).

Pressure Modulators

The Sure Brake System includes three pressure modulators as shown in Figure 18. There is a pressure modulator for each front brake and one pressure modulator for the two rear brakes.

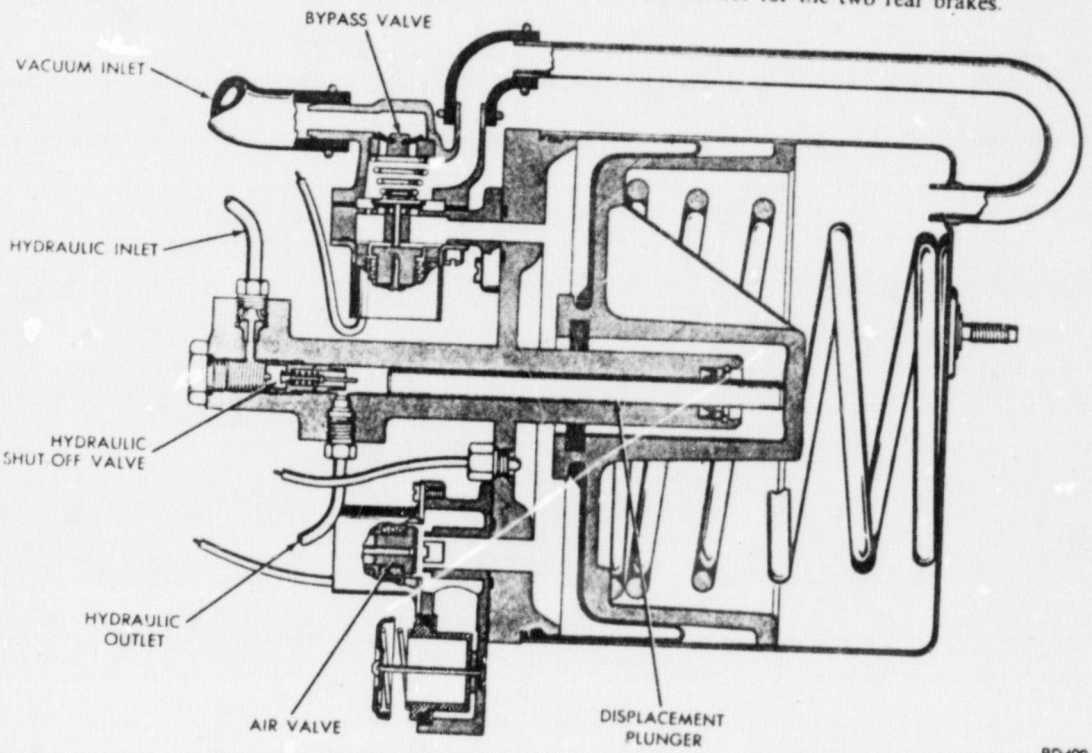

Fig. 1 - Pressure Modulator (Sectional)

The hydraulic brake tubes are routed as follows (Figure 19).

Front Wheels -- From the combination metering proportioning valve outlet port to both front brake modulators; from each modulator to one of the disc brake calipers.

Rear Wheels -- From the combination metering proportioning valve outlet port to the rear brake modulator; from the modulator to the wheel cylinders of both rear brakes.

Engine vacuum is made available to each pressure modulator. The intake manifold is connected to the pressure modulators by hoses routed as shown in Figure 18.

Each pressure modulator (Fig. 1) consists of a vacuum chamber, bypass tube, end plate, air valve, bypass valve and pressure modulator switch.

The pressure modulator vacuum chamber is divided into a front and a rear section by a diaphragm and diaphragm plate. A diaphragm return spring holds the diaphragm plate in the forward position (against the end plate). The bypass tube connects the bypass valve to the rear of the vacuum chamber.

The modulator end plate includes a hydraulic cylinder as an integral part of the plate. The cylinder has a port which is connected to the master cylinder and a port connected to the wheel brake. A shut-off valve and a displacement plunger are assembled inside the hydraulic cylinder.

The bypass valve and air valve are attached to the end plate. Both of these valves are solenoid operated. An electrical circuit connects the bypass valve on the rear pressure modulator to an amber light located on the instrument panel.

The pressure modulator switch is a spring loaded switch screwed into a threaded opening in the end plate. The switch is designed to provide a warning signal under certain abnormal conditions. (Refer to the description of the "Warning System").

Logic Controller

The logic controller (LC) is essentially a small computer and contains various electronic components. The unit (Figure 14) is encased in a container and includes the necessary cables and connectors. Electronically, the LC contains three channels, one for each of the three pressure modulators.

Wiring System

The wiring system consists of three separate wiring harnesses plus the leads from the wheel sensors and the pressure modulators. The wiring diagram in Figure 3 shows the harnesses and the other leads that make up the wiring system.

OPERATION

Engine Running - Vehicle Not in Motion

The wheel sensors do not generate any signals for transmission to the LC when the vehicle is not in motion. In the absence of signals from the wheel sensors, the LC does not send any commands to the pressure modulator.

Engine vacuum is available to the bypass valve on the end plate of the pressure modulator. The bypass valve is open in the absence of a command from the LC and vacuum is admitted to the front and rear sections of the vacuum chamber.

The air valve is closed in the absence of a command from the LC, and no atmospheric pressure is admitted to the front section of the vacuum chamber. Thus, the diaphragm is balanced in vacuum, and the diaphragm return spring holds the diaphragm plate forward against the end plate.

If the brakes are applied under these conditions, the full hydraulic pressure from the master cylinder passes through the modulator hydraulic cylinders to the calipers and wheel cylinders.

Engine Running - Vehicle in Motion

When the vehicle is in motion, an alternating current (AC) voltage is generated at each wheel sensor and sent to the LC. The frequency of the AC voltage is directly proportional to the speed of the wheel.

The LC processes the signals received from the wheel sensors to sample the speed of each wheel. If the brakes are not applied or if they are applied lightly, the LC does not send any commands to the pressure modulator.

When the brakes are applied with greater force, the LC, based on the signals received from the wheel sensors, determines the rate at which each wheel is decelerating. If the rate of decelerations is great (at a point that might produce excessive wheel slippage or wheel lockup), the LC sends a command to the modulator that controls the braking for the wheel or wheels concerned.

The command from the LC does two things at the pressure modulators:

(1) It closes the bypass valve. This shuts off the vacuum to the front section of the vacuum chamber.

(2) It opens the air valve. This permits atmospheric pressure to enter the front section of the vacuum chamber. In addition, the LC rear modulator air valve channel completes an electrical circuit to the amber light on the instrument panel, and the amber light comes on.

With vacuum in the rear section and atmospheric pressure in the front section a pressure differential is created. The return spring is compressed and the

diaphragm and diaphragm plate move slightly to the rear. This permits the displacement plunger to move slightly to the rear.

NOTE: For descriptive purposes, any diaphragm plate movement that compresses the diaphragm return spring is described as "to the rear", and any movement toward the end plate is described as "forward".

A slight movement of the displacement plunger to the rear closes the shut-off valve in the hydraulic cylinder. Closing the shut-off valve isolates the calipers or wheel cylinders concerned from master cylinder hydraulic pressure.

The continued movement of the displacement plunger to the rear provides additional space for the brake fluid trapped between the hydraulic shut-off valve and the caliper or wheel cylinders. This permits a small amount of fluid to return from the caliper or wheel cylinders to the modulator, and thus reduces the hydraulic pressure at the caliper or wheel cylinders. With the pressure reduced, the brakes are released, and the wheel speed starts to increase.

The LC, which continuously analyzes the signals received from the wheel sensors, detects the increase in wheel speed. Depending upon the rate of increase in wheel speed, one or both commands (air valve and bypass valve) are removed from the modulator. This, in turn, may accomplish two things:

(1) Close the air valve. This prevents atmosphere from entering the front section of the vacuum chamber.

(2) Open the bypass valve. This makes engine vacuum available to both the front and rear sections of the vacuum chamber.

With vacuum in both the front and rear sections, the diaphragm is balanced in vacuum, and the return spring moves the diaphragm plate forward against the end plate.

The movement of the diaphragm plate also moves the displacement plunger forward. The forward movement of the plunger decreases the space for the brake fluid trapped between the hydraulic shut-off valve and the caliper or wheel cylinders. This forces fluid back to the caliper or wheel cylinders and thus increases the hydraulic pressure to re-apply the brakes. The LC, by controlling the air valve and bypass valve, determines the rate at which the hydraulic pressure increases.

Under some conditions, the displacement plunger may move forward far enough to open the hydraulic shut-off valve. If this happens, the driver may notice a slight drop in the brake pedal.

The cycle described above is repeated during a hard brake application until the vehicle speed has been reduced to approximately 5 MPH or the driver decreases the pressure on the brake pedal.

Each time the rear modulator bypass valve is actuated (closed), the amber light on the instrument panel comes on momentarily to inform the driver that the Sure Brake System is in operation.

At the end of a brake stop, the diaphragm plate and displacement plunger should always move forward far enough to open the hydraulic shut-off valve in the pressure modulator. When this happens, the brake pedal may drop slightly as noted above.

Exercise Cycle

If the car engine is started with the brake pedal depressed (stop lights on), the pressure modulators go through two exercise cycles. When the ignition switch is turned from the OFF to the START position all three modulators cycle once, and when the switch returns from the START to the ON position the modulators cycle again. These cycles are to insure that the system is functioning properly. The cycles can be heard under some conditions (in a garage or a quiet place), but should not be a cause for concern.

Warning System

The Sure Brake System includes a secondary system to warn the driver of certain types of failures in the system. The warning system uses the vehicle's brake warning light to warn the driver that a failure exists.

The warning system will cause the brake warning light to come on under the following conditions:

(1) If the pressure modulator is activated (diaphragm and plate displaced to rear) in the absence of a brake light signal.

(2) If the LC sends a signal to open the air valve on a modulator in the absence of a signal to close the bypass valve.

(3) If the electrical continuity of the air valve lead wire is broken.

(4) If all speed sensor signals are not received at the LC, or if the signals are not properly converted in the LC at speeds above 15 MPH.

SERVICE PROCEDURES

DIAGNOSIS TESTING

In case of a malfunction in the sure brake system, the following trouble shooting procedure should be followed to properly diagnose the system. The flow chart (Fig. 2) has been included as a trouble-shooting guide.

A few important precautions should be taken to prevent damage to the components.

(1) **NEVER** connect a test lead to a modulator for

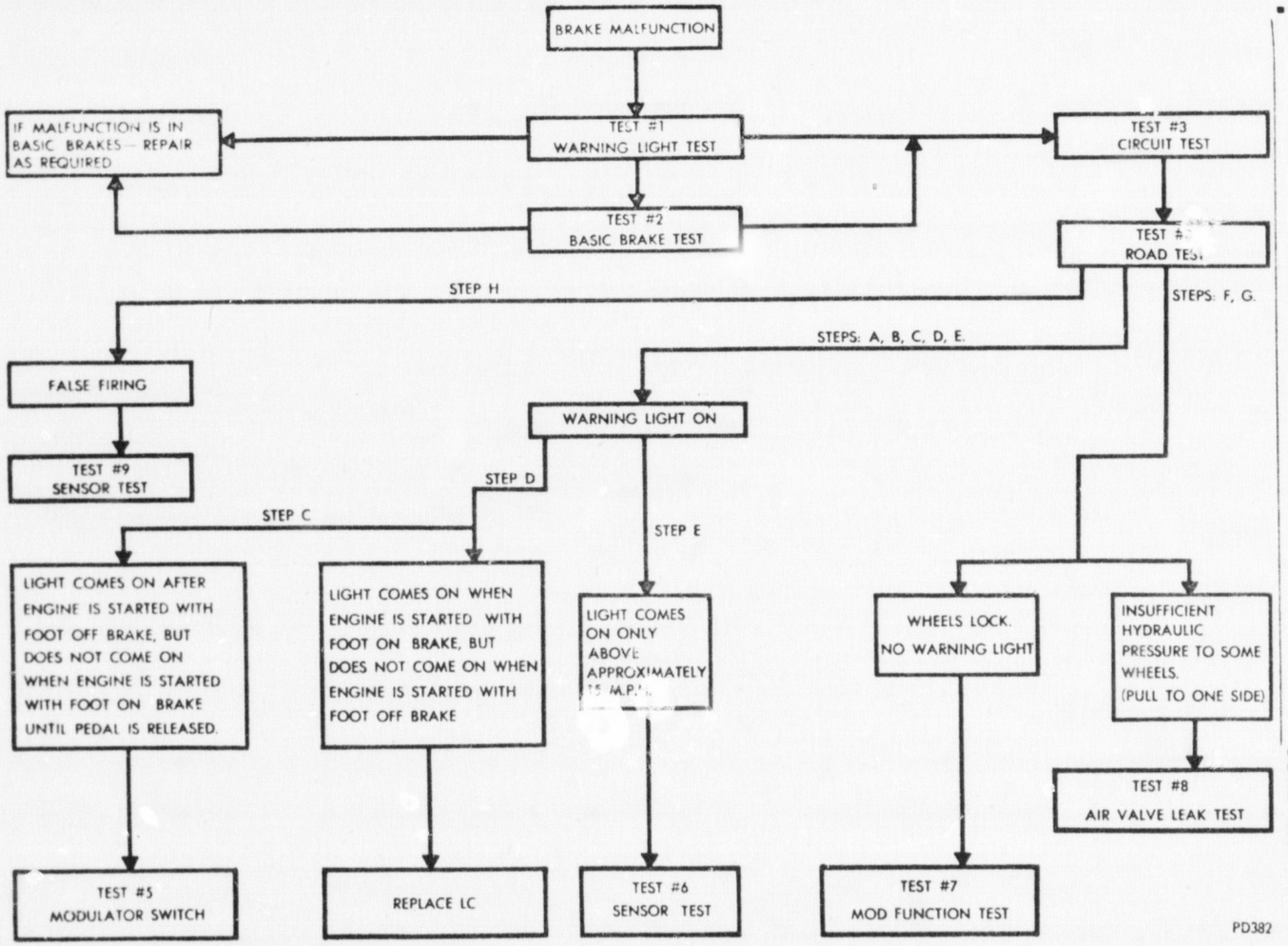

Fig. 2 - Trouble Shooting Flow Chart

E-880
[PX 155, P 5-61]
[PX 155, P 5-61]

more than 30 seconds at a time. Any time length greater than 30 seconds can damage the valve solenoid coil which in turn could burn out the logic controller.

(2) When reconnecting any electrical circuit, take special care to insure that each terminal and/or connection is made properly and securely.

(3) If for some reason, the hydraulic system has been opened, it should be bled carefully. Any air in the system can seriously reduce the systems performance.

TEST NO. 1 WARNING LIGHT TEST

Step A

If the brake warning light is not on, turn the ignition switch to START. The light should come on while the engine is cranking.

If the warning light does not come on while the engine is cranking, replace the bulb or repair the warning light circuit as necessary.

If the light stays on after the bulb is replaced or the circuit is repaired, perform Step B, below, to determine if the malfunction is in the Sure Brake System or in the basic brake system.

If the light comes on while the engine is cranking and goes off when the engine starts, perform Test No. 2, Basic Brake Test.

Step B

If the brake warning light is on, disconnect the lead from the brake warning light switch on the combination valve. Refer to Figure 20 for switch location.

If the warning light goes out when the lead is disconnected, the malfunction is in the basic brake system. Refer to instructions covering the basic brake system.

If the failure light does not go out, the malfunction is in the Sure Brake System. Perform Test No. 3, Electrical Circuit Checks.

TEST NO. 2 BASIC BRAKE TEST

Step A

Disconnect L.C. Connectors located behind right side lining in luggage compartment (Figure 4) and vacuum line. Vacuum line from intake manifold must be plugged (Figure 18).

Step B

Make brief road test to evaluate performance of basic brake system.

Step C

If braking appears normal, proceed to Test 3. If not, repair basic brake system, reconnect L. C. leads and vacuum line, and retest Sure-Brake system. If warning light comes on or system does not perform properly, proceed to Test No. 3.

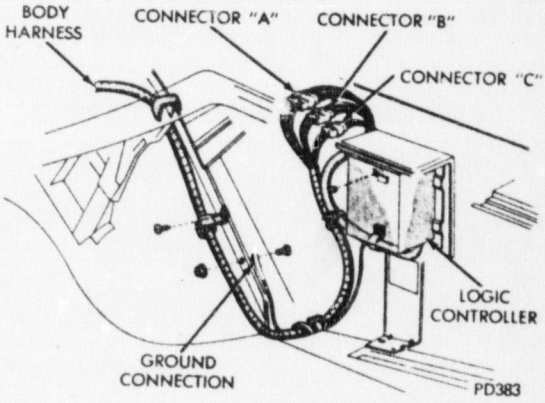

Fig. 4 - Body Harness to Logic Controller Connectors

TEST NO. 3 ELECTRICAL CIRCUIT CHECKS

Step A Checks at Logic Controller

Make the measurements listed in the following table at Connectors A, B, and C (Fig. 4). The connectors should be disconnected, except for those measurements indicated with a double asterisk (**). All readings must be obtained from the terminals on the side of the connector attached to the body harness (Figure 7) except the last measurement which is made on the logic controller side of the connector.

If any reading is not as specified, refer to the step indicated for additional measurements or connections that must be made.

CAUTION: Make all resistance measurements with the ignition switch OFF. Also be careful to avoid touching terminal K-7 while making resistance measurements because a voltage is present at K-7 whether ignition switch is ON or OFF; otherwise, the ohmmeter may be damaged.

After the circuit checks are completed, be sure that all connectors are properly mated.

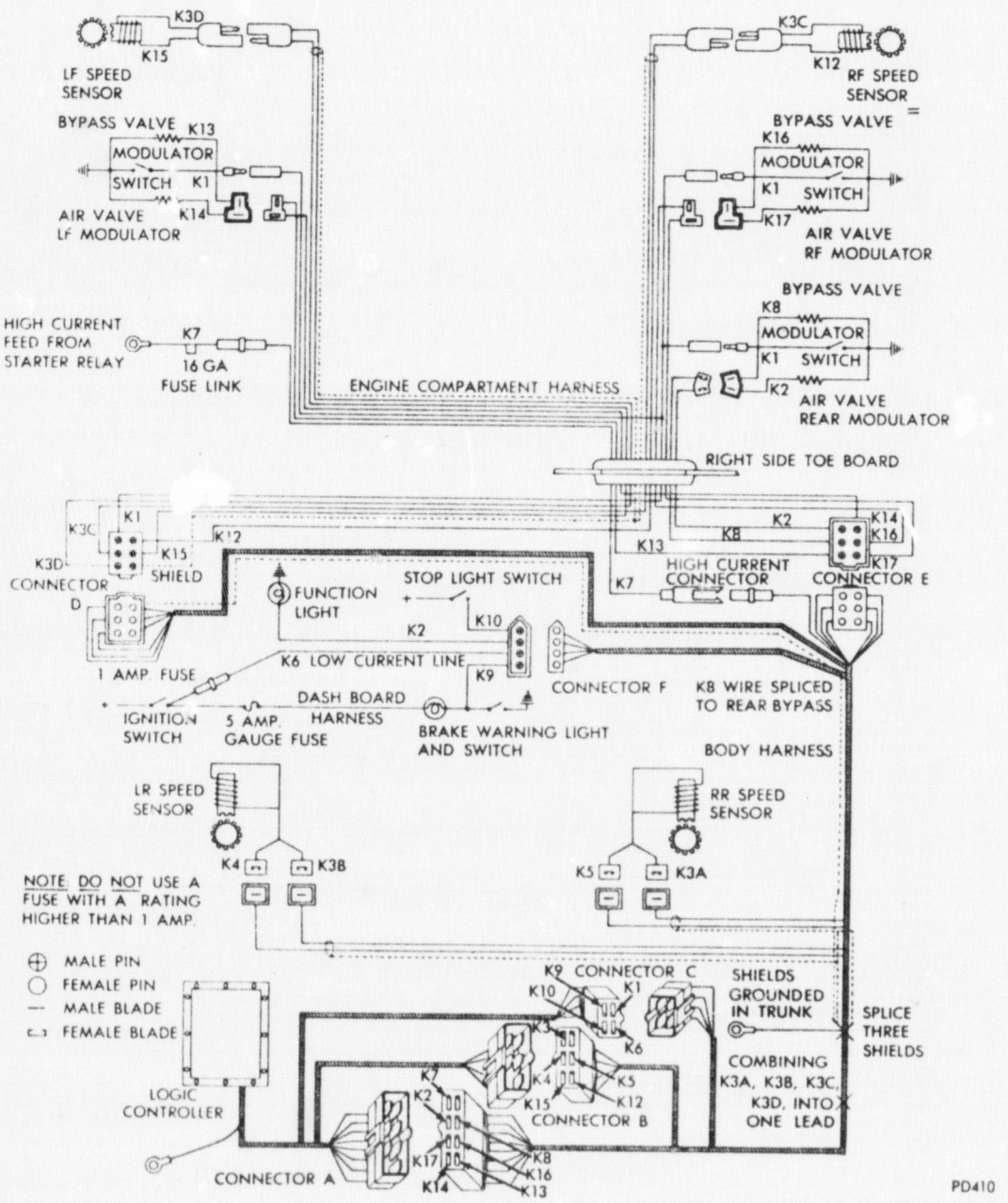

Fig. 3 - Sure Brake Wiring Diagram

5-64 SURE BRAKE

BETWEEN	AND	MEASURE	IGN. SWITCH	BRAKE PEDAL	READING SHOULD BE	IF NOT, REFER TO
K-1	Gnd	Ohms	Off	Released	Above 10,000	Step B
K-2	Gnd	Ohms	Off	Released	3.0 - 5.0	Step C
K-3	Gnd	Ohms	Off	Released	Above 50,000	Step D
K-4	Gnd	Ohms	Off	Released	Above 50,000	Step E
K-4	K-3	Ohms	Off	Released	250-350	Step E
K-5	Gnd	Ohms	Off	Released	Above 50,000	Step E
K-5	K-3	Ohms	Off	Released	250-350	Step E
K-8	Gnd	Ohms	Off	Released	3.0 - 5.0	Step C
K-12	Gnd	Ohms	Off	Released	Above 50,000	Step F
K-12	K-3	Ohms	Off	Released	1000-1300	Step F
K-13	Gnd	Ohms	Off	Released	3.0 - 5.0	Step C
K-14	Gnd	Ohms	Off	Released	3.0 - 5.0	Step C
K-15	Gnd	Ohms	Off	Released	Above 50,000	Step G
K-15	K-3	Ohms	Off	Released	1000-1300	Step G
K-16	Gnd	Ohms	Off	Released	3.0 - 5.0	Step C
K-17	Gnd	Ohms	Off	Released	3.0 - 5.0	Step C
K-6	Gnd	DC Volts	On	Released	12*	Step H
K-7	Gnd	DC Volts	Off	Released	12*	Step J
K-9	Gnd	DC Volts	On	Released	12*	Step J
K-10#	Gnd	DC Volts	Off	Released	0 w/headlights ON	Step K
K-10	Gnd	DC Volts	Off	Applied	12*	Step L
K-2**	Gnd	DC Volts	On	Applied	0	Step M
K-8**	Gnd	DC Volts	On	Applied	0	Step M
K-13**	Gnd	DC Volts	On	Applied	0	Step M
K-14**	Gnd	DC Volts	On	Applied	0	Step M
K-16**	Gnd	DC Volts	On	Applied	0	Step M
K-17**	Gnd	DC Volts	On	Applied	0	Step M
K-3##	Gnd	Ohms	Off	Released	0	Step N

* Should be same as battery voltage within 1 volt.
** Make measurements with all connectors connected.
# Make measurement with headlights ON.
Make measurement between K-3 on logic controller side of connector and rear bumper.

Step B Modulator Switch Circuit

NOTE: After finding an apparent circuit failure, reconnect all connectors except Connectors A, B and C (at the logic controller) (Fig. 4), and repeat the corresponding measurement as specified in the table in Step A.

Disconnect the modulator switch connectors (Figure 5). Measure the resistance between the modulator switch side of the connectors (Figure 8) and ground. If any reading is below 10,000 ohms, the corresponding modulator or modulator switch is faulty, and the modulator must be replaced.

If the readings are above 10,000 ohms, the engine compartment or body harness is faulty. Re-connect modulator and continue to next step.

Disconnect Connector D (Figure 6) located under the right side of the dashboard in the passenger compartment.

On the engine compartment harness side of Connector D, measure the resistance between K-1 and ground (Figure 7). If the reading is correct (above 10,000 ohms), the body harness is faulty and must be replaced. If reading is below 10,000 ohms, the engine compartment harness is faulty and must be replaced.

Step C Air Valve and Bypass Valve Circuits

NOTE: After finding an apparent circuit failure, reconnect all connectors except Connectors A, B and C (at the logic controller), and repeat the corresponding measurement as specified in the table in Step A.

Disconnect the electrical connector leading to the corresponding modulator (Figure 5). On the modulator side of the connector, measure the resistance between the terminal that had the incorrect reading and ground (Figure 8).

If the reading is still incorrect, the appropriate modulator is faulty and must be replaced.

If the reading is correct (3.0 - 5.0 ohms) at the modulator connector, the engine compartment or body harness is faulty. Reconnect modulator connector and continue to next step.

Disconnect Connector E (Figure 6) located under the right side of the dashboard in the passenger compartment.

On the engine compartment side of Connector E, measure the resistance between the terminal that had the incorrect reading and ground (Figure 7).

If the reading is correct (3.0 - 5.0 ohms), the body harness is faulty and must be replaced. If the reading is not correct, the engine compartment harness is faulty and must be replaced.

Step D Speed Sensor Ground Circuit

NOTE: After finding an apparent circuit failure, reconnect all connectors except Connectors A, B and C (at the logic controller), and repeat the corresponding measurement as specified in the table in Step A.

Disconnect the front wheel speed sensor connectors (Figure 5).

On the speed sensor side of the connector, measure the resistance between either terminal and ground (Figure 9).

If the reading is below 50,000 ohms, the speed sensor is faulty and must be replaced.

If readings are correct, disconnect Connector D (Figure 6) located under the right side of the dashboard in the passenger compartment.

On the engine compartment harness side of Connector D, measure the resistance between K-3C and body ground and between K-3D and body ground (Figure 7).

If both readings are correct (above 50,000 ohms), remove the rear seat and disconnect the rear wheel speed sensor connectors (Figure 6).

On the speed sensor side of the connectors, measure the resistance between each of the four termi-

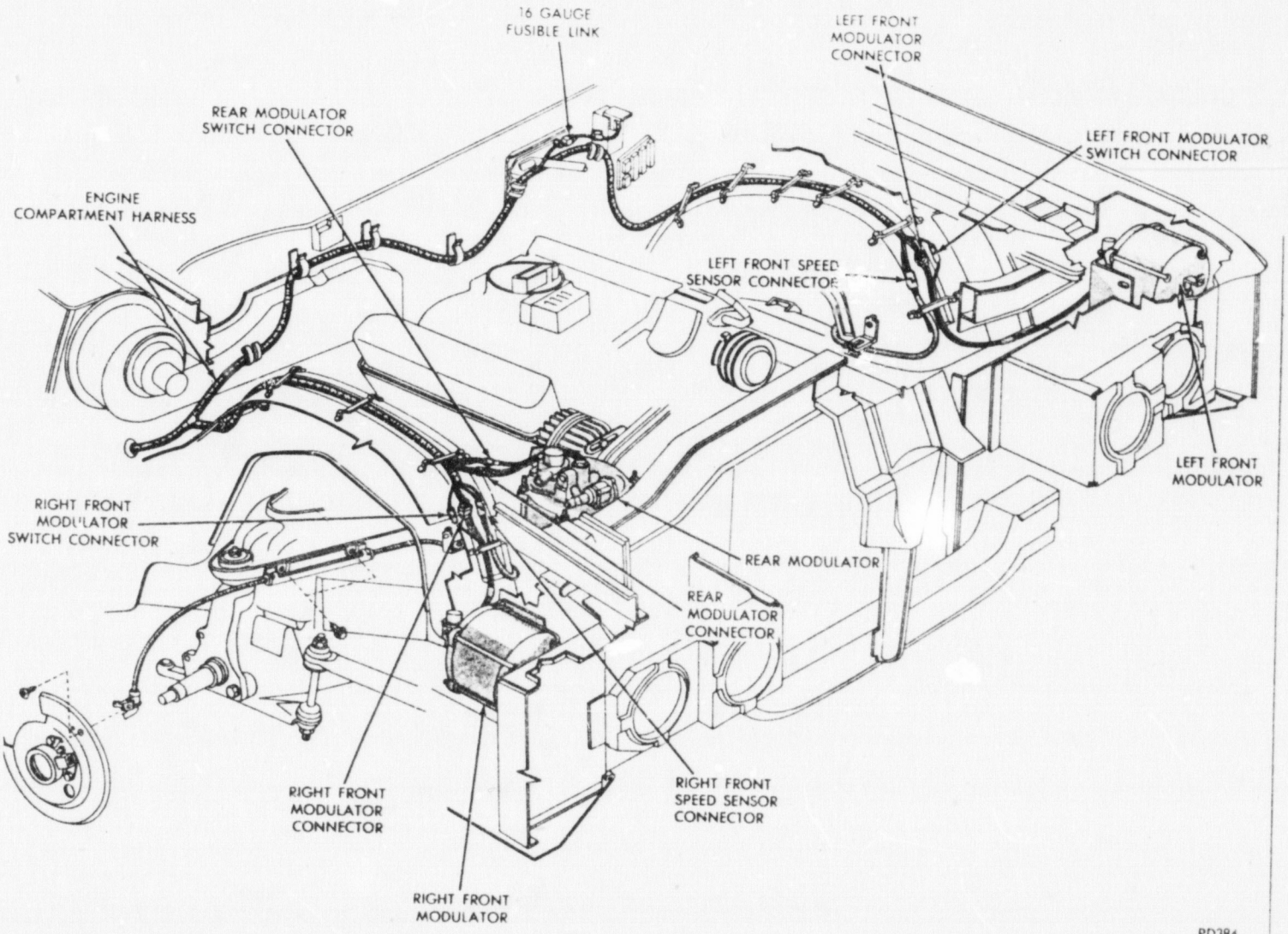

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Fig. 5 - Engine Compartment Harness Connectors

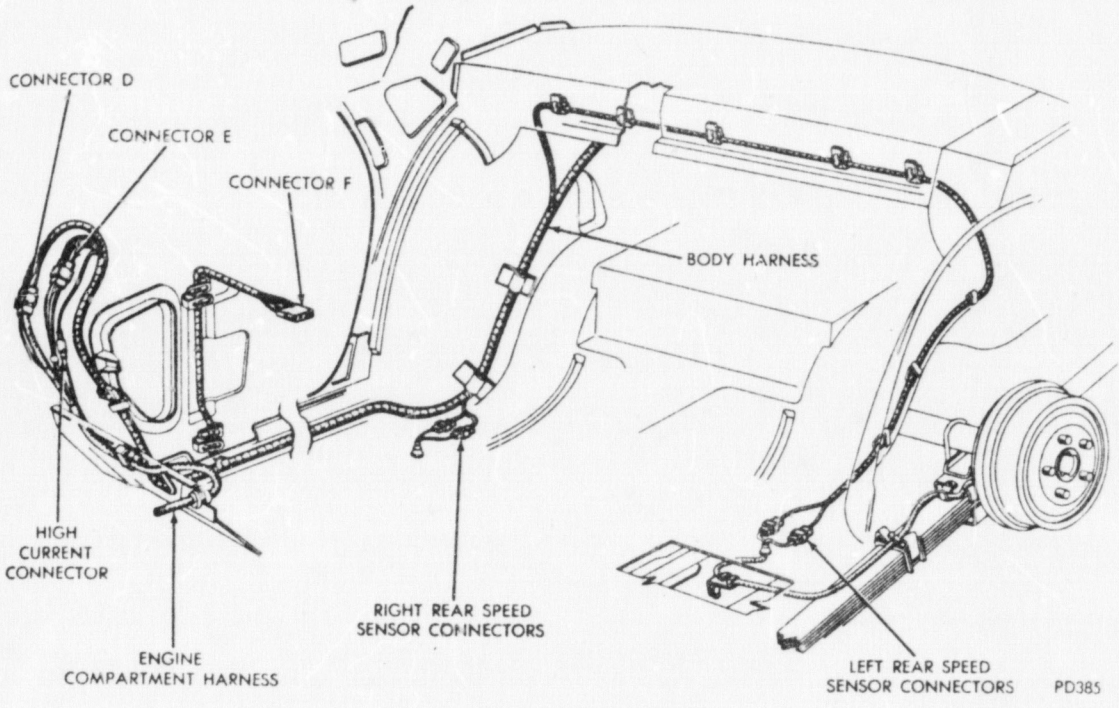

Fig. 6 - Body Harness Connectors

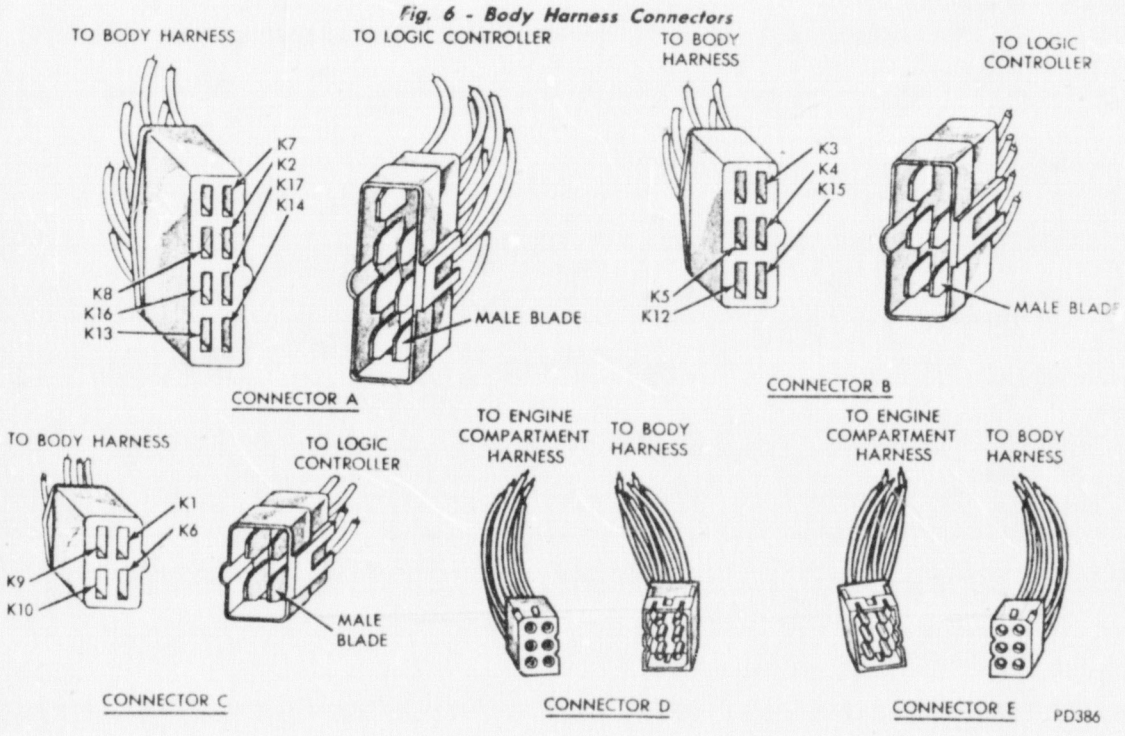

Fig. 7 - Connectors A, B, C, D and E

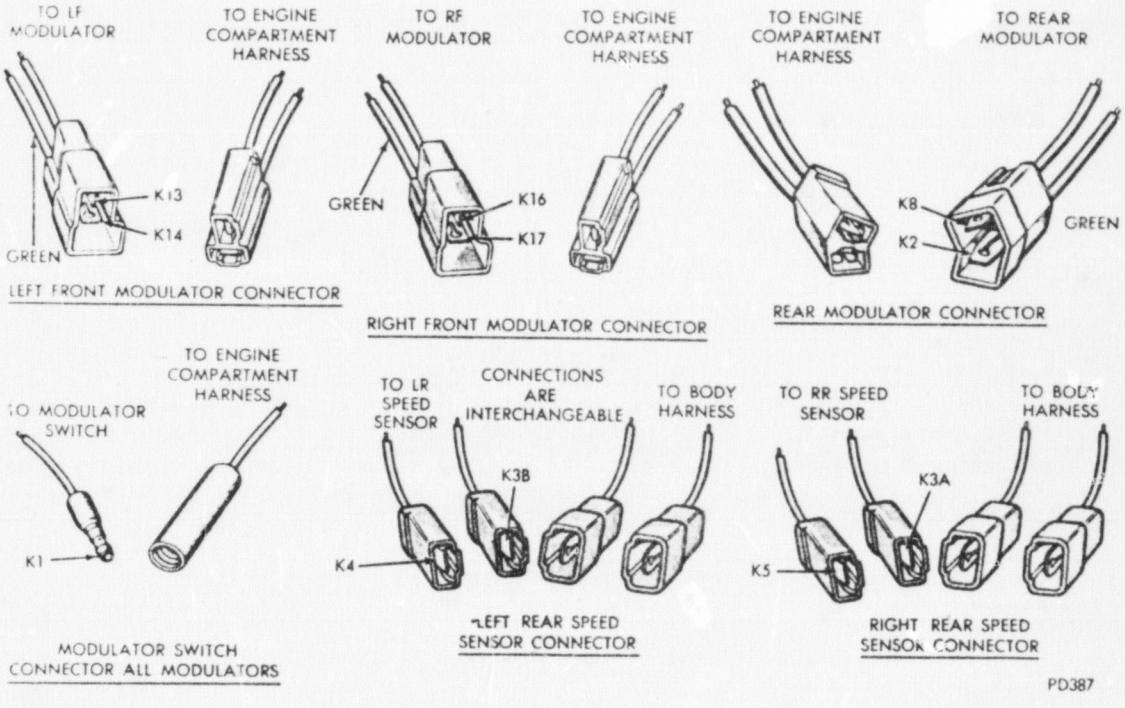

Fig. 8 - Electrical Connectors

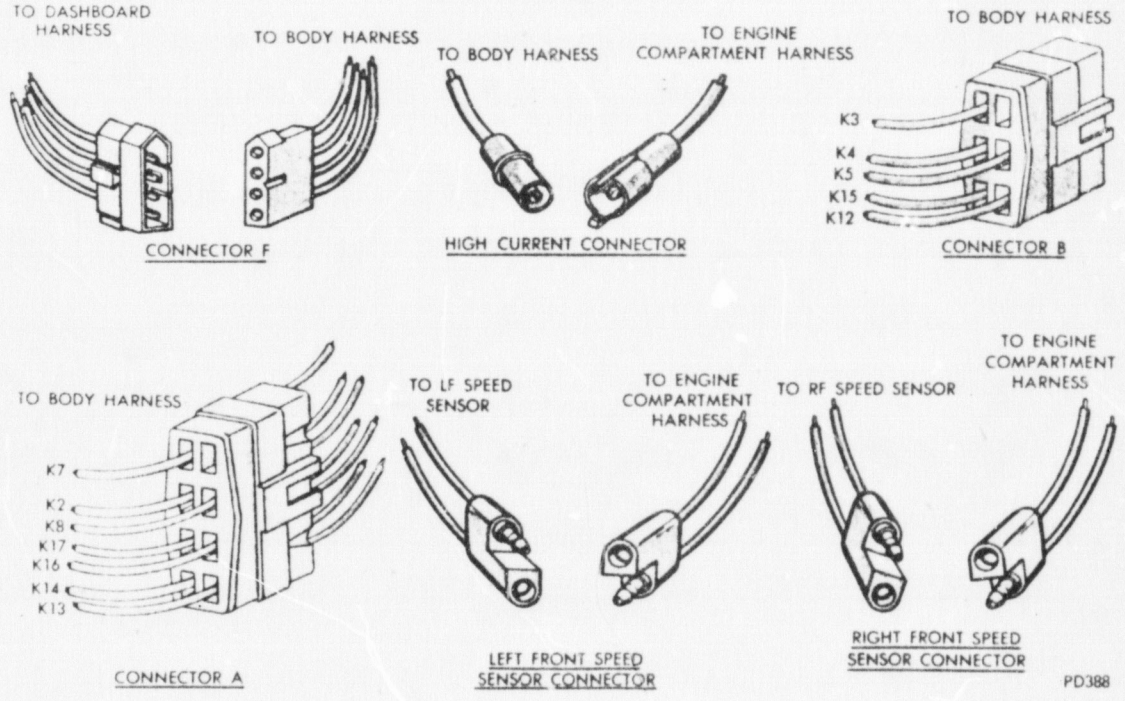

Fig. 9 - Electrical Connectors

nals and body ground (Figure 8).

If all readings are correct (above 50,000 ohms), the body harness is faulty and must be replaced.

If any reading at a rear wheel sensor connector is below 50,000 ohms, the speed sensor attached to the connector is faulty and must be replaced.

Step E Rear Speed Sensor Circuits

NOTE: After Finding an apparent circuit failure, reconnect all connectors except Connectors A, B and C (at the logic controller), and repeat the corresponding measurement as specified in the table in Step A.

Remove the rear seat and disconnect the rear wheel speed sensor connectors (Figure 6) in the line that has the incorrect reading.

On the speed sensor side of the connectors, measure the resistance between either of the terminals and body ground (Figure 8). The readings should be above 50,000 ohms.

On the speed sensor side of the connectors, also measure the resistance between the terminals in the two connectors. The reading should be 250-350 ohms.

If all readings are correct, the body harness is faulty and must be replaced.

If any reading is incorrect, the corresponding speed sensor is faulty and must be replaced.

Step F Right Front Speed Sensor Circuit

NOTE: After finding an apparent circuit failure, reconnect all connectors except Connectors A, B and C (at the logic controller), and repeat the corresponding measurement as specified in the table in Step A.

Disconnect the right front wheel speed sensor connector (Figure 5).

On the speed sensor side of the connector (Figure 9), measure the resistance between each terminal and ground, and between the two terminals.

If all readings are correct (each terminal to ground - above 50,000 ohms; terminal to terminal - 1000 to 1300 ohms), the engine compartment or body harness is faulty. Reconnect speed sensor connector.

If any reading is incorrect, the right front speed sensor is faulty and must be replaced.

Disconnect Connector D (Figure 6) located under the right side of the dashboard in the engine compartment.

On the engine compartment harness side of Connector D (Figure 7), measure the resistance between K-12 and ground, and between K-12 and K-3C.

If both readings are correct (K-12 to ground - above 50,000 ohms; K-12 to K-3C - 1000 to 1300 ohms), the body harness is faulty and must be replaced. If either reading is incorrect, the engine compartment harness is faulty and must be replaced.

Step G Left Front Speed Sensor Circuit

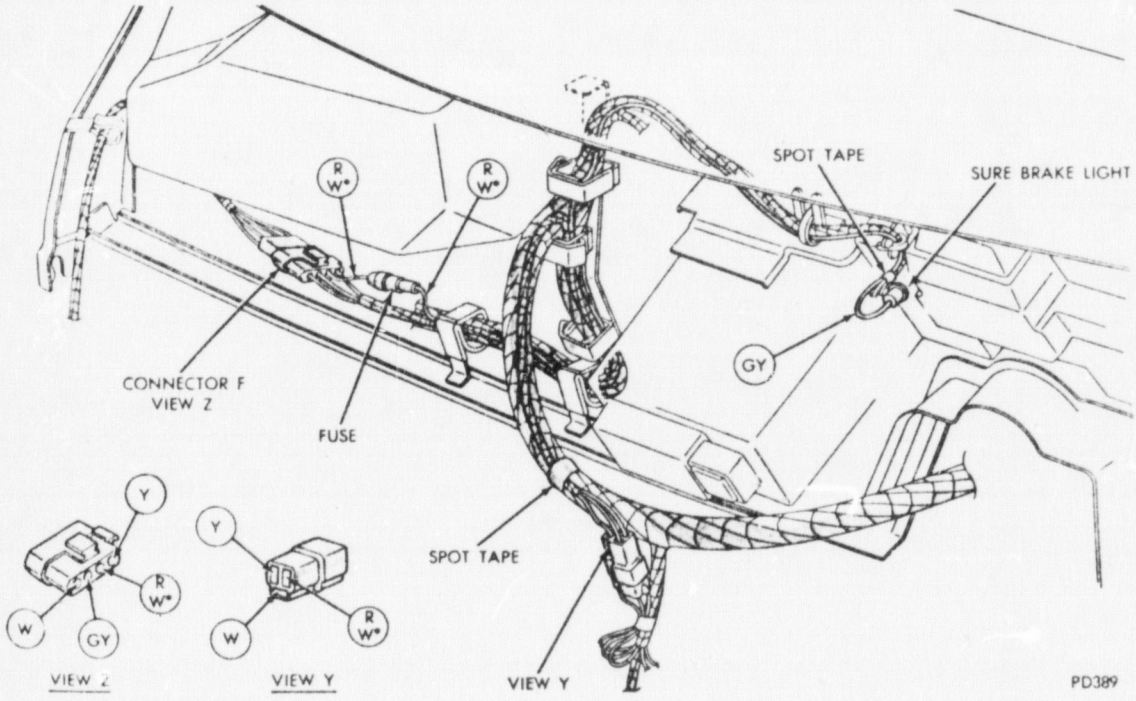

Fig. 10 - Dashboard Harness

NOTE: After finding an apparent circuit failure reconnect all connectors except Connectors A, B and C (at the logic controller), and repeat the corresponding measurement as specified in the table in Step A.

Disconnect the left front wheel speed sensor connector (Figure 5).

On the speed sensor side of the connector (Figure 9), measure the resistance between each terminal and ground, and between the two terminals.

If all readings are correct (each terminal to ground - above 50,000 ohms: terminal to terminal - 1000 to 1300 ohms), the engine compartment or body harness is faulty. Reconnect speed sensor connector.

If any reading is incorrect, the left front speed sensor is faulty and must be replaced.

Disconnect Connector D (Figure 6) located under the right side of the dashboard in the engine compartment.

On the engine compartment harness side of Connector D (Figure 7), measure the resistance between K-15 and ground, and between K-15 and K-3D.

If both readings are correct (K-15 to ground - above 50,000 ohms; K-15 to K-3D - 1000 to 1300 ohms), the body harness is faulty and must be replaced. If either reading is incorrect, the engine compartment harness is faulty and must be replaced.

Step H Low Current Circuit

NOTE: After finding an apparent circuit failure, reconnect all connectors except Connectors A, B and C (at the logic controller), and repeat the corresponding measurement as specified in the table in Step A.

Check the 1 Amp. fuse in the K-6 line between Connector F and the ignition switch. (Under dash, not in fuse block). (Figure 10).

Replace the fuse if it is faulty.

If fuse is OK, disconnect Connector F (Figure 10) located under the right side of the dashboard in the passenger compartment.

On the dashboard side of Connector F (Figure 9), measure the DC voltage between K-6 and ground (with ignition switch in the ON position).

If the reading is correct (battery voltage), the body harness is faulty and must be replaced.

If the reading is incorrect, the instrument panel overlay harness is faulty and must be repaired or replaced.

Step I High Current Circuit

NOTE: After finding an apparent circuit failure, reconnect all connectors except Connectors A, B and C (at the logic controller), and repeat the corresponding measurement as specified in the table in Step A.

Check the 16 Gauge Fusible Link in the high current line located in the engine compartment (Figure 5). Replace the fusible link, if necessary.

If the fusible link is good and battery voltage is present at the high current feed on the starter relay, disconnect the high current connector (Figure 6) located under the right side of the dashboard in the passenger compartment.

Measure the DC voltage between the engine compartment harness side of the high current connector and ground (Figure 9).

If the reading is correct (battery voltage), the body harness is faulty and must be replaced.

If no voltage is present the engine compartment harness is faulty and must be replaced.

Step J Warning Light Circuit

NOTE: After finding an apparent circuit failure, reconnect all connectors except Connectors A, B and C (at the logic controller), and repeat the corresponding measurement as specified in the table in Step A.

Disconnect Connector F (Figure 10) located under the right side of the dashboard in the passenger compartment.

On the dashboard side of Connector F (Figure 9), measure the DC voltage between K-9 and ground (with ignition switch in the ON position).

If the reading is correct (battery voltage), the body harness is faulty and must be replaced.

If voltage is not present, the instrument panel overlay or instrument panel harnesses are faulty and must be repaired or replaced.

Step K Voltage Feedback

NOTE: After finding an apparent circuit failure, reconnect all connectors except Connectors A, B and C (at the logic controller), and repeat the corresponding measurement as specified in the table in Step A.

Depress and release the brake pedal and check the operation of the stop lights.

If the stop lights are not functioning normally, refer to stop light switch adjustment, this Group. Or Group "8" Electrical.

After the stop light defect has been located and corrected, repeat the measurement of the DC voltage between K-10 in Connector B and ground (with the headlights ON).

If the reading is still above zero volts, check both tail light/stop light assemblies for poor ground or improper wiring and correct the defect.

Step L Stop Light to LC Circuit

NOTE: After finding an apparent circuit failure, reconnect all connectors except Connectors A, B and C (at the logic controller), and repeat the corresponding measurement as specified in the table in Step A.

Check stop lights for operation. Adjust the brake light switch or correct other defects, if necessary and recheck voltage at LC. If no voltage is present, disconnect Connector F (Figure 10) located under

the right side of the dashboard in the engine compartment.

On the instrument panel harness side of Connector F, measure the DC voltage between K-10 (Figure 9) and ground (with brakes applied).

If the reading is correct (battery voltage), the body harness is faulty and must be replaced.

If the reading is incorrect, the instrument panel harness is faulty and must be replaced.

Step M Logic Controller Circuits

If the reading is incorrect (above zero volts), the logic controller is faulty and must be replaced.

Step N LC Ground

Remove the bolt that secures the logic controller ground wire to the brace in the luggage compartment (Figure 4).

Clean the eye on the end of the wire and the surface of the brace where the eye is attached. Be sure that any rust, dirt or corrosion is removed.

Secure the ground wire to the brace and measure the resistance between K-3 on the logic controller side of Connector B (Figure 7) and a good ground connection on the rear bumper.

If the reading is correct (zero ohms), the ground connection was faulty and the problem has been corrected.

If the reading is above zero ohms, the logic controller is faulty and must be replaced.

TEST NO. 4 ROAD TEST

NOTE: Make sure LC and vacuum lines are connected.

Step A

Start engine with foot off brake - observe failure light.

Shut off engine.

Step B

Restart with foot on brake - observe failure light.

Step C

If brake failure light came on in (A) but not in (B) perform **Test #5** (modulator switch test).

Step D

If brake failure light came on in (B) but not in (A) replace Logic Controller.

If no lights in (A) or (B) continue.

Step E

Drive car at 20 mph with foot off brake. If light comes on perform **Test #6** (sensor test).

If false firing suspected, go to **Step H.**

If no lights in (E), continue.

Step F

Drive car at 45 mph on slippery surface (i.e., ice, snow, sand, gravel, wet blacktop, etc.). Apply brakes hard to lock or attempt to lock all four wheels. Observe for the following:

Pull to right or left - perform **Test #8** (front mod. air valve leak test).

Lack of rear braking - go to **Step G.**

Locking of any wheel above 15 mph - go to **Test 7.**

Step G

If lack of rear brakes is suspected, disconnect both front sensor connectors (Fig. 5) (red rubber) in engine compartment.

Restart car and make hard stop on slippery surface from 45 mph. Observe for following:

If rear modulator cycling can be heard or felt, rear brakes and rear Sure-Brake system are operational.

If rear wheels lock, perform **Test #7** (rear modulator test).

If rears do not lock and modulator does not cycle, perform **Test #8** (air valve leak test).

Step H

Drive car on rough road with brake lightly applied (sufficient pedal force to turn on brake light). If no false firing occurs, drive car at 60 mph with brake lightly applied. If false firing occurs perform **Test #9** (false firing cycling test). If cause for false firing has not been discovered at this point, suspect Logic Controller.

TEST NO. 5 MODULATOR SWITCH TEST

Check the modulators as follows:

With the car engine running, disconnect all three modulator switch connectors in the engine compartment (Figure 5). Measure the resistance between the modulator switch side of the connector (Figure 8) and ground. If any reading is less than 10,000 ohms, replace the corresponding modulator.

TEST NO. 6 SPEED SENSOR OUTPUT CHECK

Step A Check the rear speed sensor output as follows:

With the rear wheels just off the floor, start the engine and drive the rear wheels 5 to 6 miles per hour.

With all connectors connected, measure the AC voltage between K-4 in Connector B and K-3 in Connector B (Figures 4 and 9). Make the measurement where the wires go into the back of the connectors.

The voltmeter should read at least .2 volts AC. If the reading is less than .2 volts, go to Step B, below.

If the reading is .2 volts or more, perform the balance of this step.

With all connectors connected, measure the AC voltage between K-5 in Connector B and K-3 in Connector B. Make the measurement where the wires go into the back of the connectors.

The voltmeter should read at least .2 volts AC. If the reading is less than .2 volts, go to Step B, below.

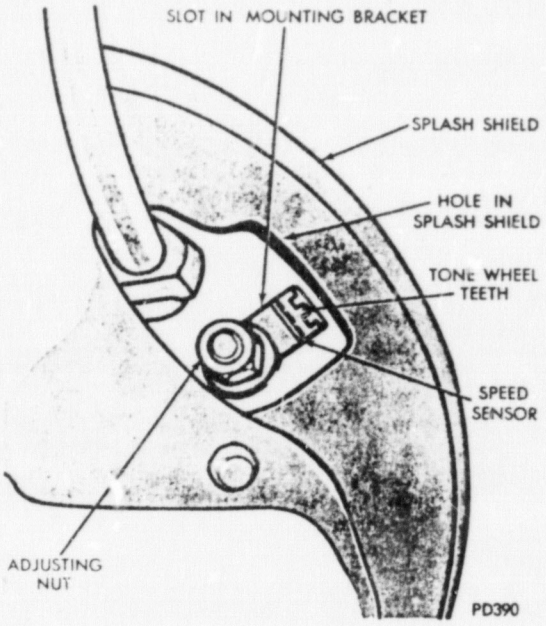

Fig. 11 - Adjusting Front Speed Sensor Position

If the reading is .2 volts or more, go to Step C, below.

Turn the engine OFF.

Step B Inspect the appropriate rear speed sensor as follows:

Remove the rear wheel and drum, and check that the sensor mounting bracket holds the sensor knurled wheel against the rubber drive band in the drive ring. Then remove the drive ring.

Check the sensor (Figure 13) for damage to the tone wheel teeth, the sensor mounting bracket and the sensor lead. Be sure that the tone wheel can be turned with the fingers. Replace any faulty parts.

Inspect the rubber drive band that is pressed into the drive ring (Figure 13). If the rubber band slips inside the ring or the band is badly worn, replace the drive ring assembly.

Check the sensor knurled wheel for deposits (rubber, lining dust, etc.). If the deposits are excessive or uneven, clean the knurled area with a knife.

Install the drive ring, drum and wheel.

Repeat **Step A**, above. If the AC voltage output is still less than .2 volts, replace the speed sensor assembly.

Step C Check the front speed sensor output as follows:

With the front wheels just clear of the floor, rotate the left front wheel, by hand, at the rate of one revolution per second. This is equivalent to approximately 5 miles per hour.

NOTE: It may be necessary to pry the disc brake pads back from the disc so that the wheel rotates freely. CAUTION: Do not damage pads by prying on lining surface.

With all connectors connected, measure the AC voltage between K-15 in Connector B and K-3 in Connector B (Figure 9). Make the measurement where the wires go into the back of the connectors.

The voltmeter should read at least .2 volts AC. If the reading is less than .2 volts, go to Step D, below.

If the reading is .2 volts or more, perform the balance of this step.

Rotate the right front wheel, by hand, at the rate of one revolution per second.

With all connectors connected, measure the AC voltage between K-12 in Connector B and K-3 in Connector B. Make the measurement where the wires go into the back of the connectors.

The voltmeter should read at least .2 volts AC. If the reading is less than .2 volts, go to Step D, below.

If the reading is .2 volts or more, go to Step E, below.

Step D Inspect the appropriate front speed sensor as follows:

Raise the car on a hoist, and use a narrow (1/4" wide), .020" feeler gauge to check the gap between the speed sensor and the tone wheel (Figure 11). The gap should be .020" maximum. The sensor contains a magnet which may attract the feeler gauge. This may cause the air gap to feel correct, when it may be excessive.

NOTE: A gauge may be made from a piece of .020" shim stock, if desired. If the gap is incorrect, loosen the sensor locknut, adjust the sensor position, and tighten the locknut to 70-90 inch-pounds. Rotate the wheel to be sure that the sensor does not touch the tone wheel, used sensor only. A new sensor will touch. See "Component Removal and Installation".

Repeat **Step C**, above. If the AC voltage output is still less than .2 volts, replace the speed sensor assembly, and inspect tone wheel for damaged or chipped teeth. If teeth in the tone-wheel are missing, the hub, rotor, and tone-wheel assembly must be replaced.

Step E

If all the speed sensors are functioning properly, the logic controller is faulty and must be replaced.

TEST NO. 7 MODULATOR FUNCTION TEST

Step A Check the vacuum supply as follows:

Visually inspect all vacuum hoses in the engine compartment for damage, and check that all hose connections are tight. Replace any damaged hoses, and tighten any loose connections.

Start engine and listen for hissing sound indicating vacuum leak. Repair leak if located.

After all leaks (if any) have been repaired, discon-

nect the vacuum hose at the rear modulator (Figure 18), and connect a vacuum gauge between the hose and the rear modulator vacuum inlet. Connect all vacuum hoses.

With engine running, the vacuum gauge should read normal engine vacuum. If not, re-check for vacuum leak, or tune the engine, as necessary.

If the vacuum supply is adequate but **all** wheels lock up during a severe brake application and the warning light does not come on, the logic controller is faulty and must be replaced.

If the vacuum supply is adequate, one or more wheels (but not all) lock up during a severe brake application and the warning light does not come on, perform the balance of this test.

Step B Check the operation of the air valve and by-pass valve as follows:

Disconnect the electrical connector to the suspected modulator (the modulator that controls the wheel or wheels that lock up). Refer to Figure 5.

Start the engine, and note the reading on the vacuum gauge.

NOTE: The air valve and bypass valve should not be energized for more than 30 seconds and a two-minute cool-off period should follow each period the valves are energized; otherwise, the valve solenoid may overheat and be damaged.

Connect a jumper lead from the positive pole of the battery to the air valve terminal (K-2, K-14 or K-17) on the side of the connector leading to the modulator under test (Figure 8).

WARNING: Do not leave any modulator connected to battery for more than 30 seconds. Extended actuation of modulator valves will burn out coils.

The reading on the vacuum gauge should drop. If not, the modulator is faulty and must be replaced.

Connect a second jumper lead from the positive pole of the battery to the bypass valve terminal (K-8, K-13, or K-16) on the side of the connector leading to the modulator (jumper lead still connected to air valve).

The vacuum gauge reading should increase to approximately the reading noted before valves were energized.

If the vacuum gauge reading does not increase, the modulator is faulty and must be replaced.

If the vacuum gauge reading increases, remove the vacuum gauge and repeat Step B at the other two modulators.

If the vacuum readings are normal at all three modulators, perform Step C, below.

Step C Check the operation of the rear modulator as follows:

Disconnect rear modulator connector K-2 and K-8 close to the modulator, connect a jumper lead capable of reaching the battery from the modulator K-2, K-8 connector.

Raise rear wheels clear of ground, start engine, engage drive.

Apply brake with medium force. (A pedal force beyond booster run-out must not be used). If wheels do not stop, modulation is faulty.

A second man applies the K-2, K-8 jumper lead to the battery positive terminal for a maximum of 10 seconds and observe that the rear wheels begin to revolve. Should the wheels not revolve, recheck pedal pressure and retest. If the wheels do not revolve, replace modulator.

Step D Check the operation of the suspect front modulator as follows:

Disconnect front modulator connector close to the modulator, connect a jumper lead capable of reaching the battery from the modulator connector.

Raise front wheels clear of ground, check they can be rotated by hand.

Apply brake with medium force. (A pedal force beyond booster run-out must not be used).

A second man applies the jumper lead to the battery positive terminal for a maximum of 10 seconds while a third man rotates or attempts to rotate the front wheel. Should the wheel not revolve, recheck pedal pressure and retest. If the wheel does not revolve, replace modulator.

Step E Check the operation of the hydraulic check valve as follows:

Disconnect suspect modulator connector close to the modulator, connect a jumper lead capable of reaching the battery, to both terminals in the modulator connector (Fig. 8).

Start engine, apply medium brake pressure (a pedal force beyond power brake booster run-out must not be used).

Apply the jumper lead to the battery positive terminal. Then crack a bleed screw at the appropriate brake. Hold for 30 seconds – observe that fluid does not rush out and the brake pedal does not sink, indicating that the check valve is functioning correctly. Remove jumper lead and tighten bleed screw.

Should the pedal sink indicating a leaking hydraulic check valve, replace modulator.

TEST NO. 8 AIR VALVE LEAKAGE TEST

A leaking air valve can prevent full pressure from getting to the wheel brake effected. (i.e., leaking left front air valve may cause a pull to the right, etc.).

Step A

Disconnect electrical connections at the suspect modulator.

Raise suspected wheels just clear of floor.

Obtain a jumper wire long enough to reach from the battery to the modulator under test.

Disconnect the modulator connector (two circuit connector Figures 3 and 5).

Start engine and apply the brakes with moderate

force.

Apply the jumper to the bypass valve terminal o... (K 13, K-16, K-8) and attempt to turn the controlled wheel with a wrench or the lug nut.

WARNING: Do not leave valve connected for more than 30 seconds.

If the wheel will turn, repeat the test with the jumper disconnected and the engine off. If the wheel will not turn under these conditions, the air valve is leaking.

Replace the modulator.

TEST NO. 9 FALSE FIRING CYCLING TEST

NOTE: An occasional "Sure-Brake" light and modulator clicking caused by driving over a rough road or a gravel road with the brake applied lightly is normal. Should repeated firings occur on average to smooth roads at decelerations obviously less than skid levels, inspect sensors.

Step A Inspect each front speed sensor as follows:

Raise the car on a hoist, and use a narrow (1/4" wide), .020" feeler gauge to check the gap between the speed sensor and the tone wheel (Figure 11). The gap should be .020" maximum.

Note: A gauge may be made from a piece of .020" shim stock, if desired.

If the gap is incorrect, loosen the sensor locknut, adjust the sensor position, and tighten the locknut to 70-90 in. lbs. Rotate the wheel to be sure that the sensor does not touch the tone wheel.

Inspect tone wheel teeth for low tooth (.010"-.020" will cause trouble).

Step B Inspect each rear speed sensor as follows:

Remove the rear wheel and drum, and check that the sensor mounting bracket holds the sensor knurled wheel against the rubber drive band in the drive ring. Then remove the drive ring.

Check the sensor (Figure 13) for damage to the tone wheel teeth, the sensor mounting bracket and the sensor lead. Be sure that the tone wheel can be turned with the fingers. Replace any faulty parts.

Inspect the rubber drive band that is pressed into the drive ring (Figure 13). If the rubber band slips inside the ring or the band is badly worn, replace the drive ring assembly.

Check the sensor knurled wheel for deposits (rubber, li... dust, etc.). If the deposits are excessive or uneven, clean the knurled area with a knife.

Install the drive ring, drum and wheel.

Step C Make a functional check as follows:

Remove two leads from brake stoplight switch at brake pedal and install a short jumper wire across the two leads so that the stoplights are on at all times. Drive over a rough area at various speeds until the false firing readily occurs.

Disconnect one front sensor at a time (see Figure 5 for location of sensor connectors) and drive over

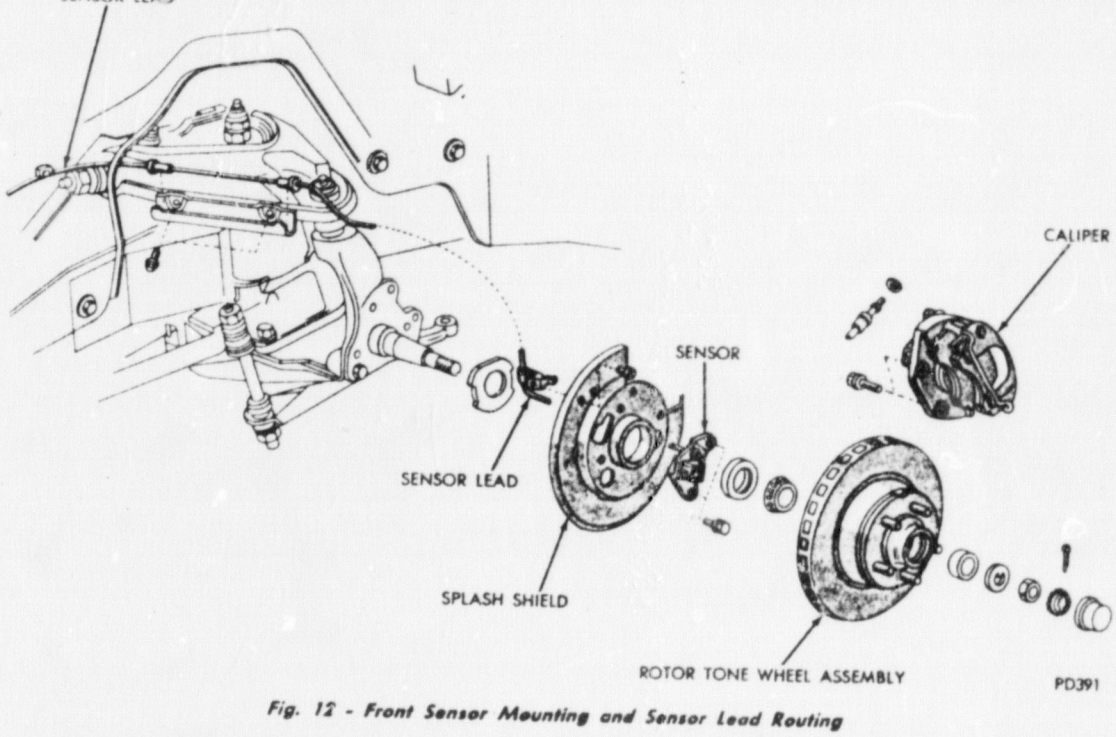

Fig. 12 - Front Sensor Mounting and Sensor Lead Routing

same area under the same conditions that produced the false firing.

When the false firing stops, replace the front sensor that is disconnected.

Should the front sensors not be the problem, remove rear seat to expose both pairs of rear sensor leads - disconnect left sensor. Make up a wire harness to connect output of right rear sensor to both right and left harness leads. Drive over the same area under the same conditions that produced the false cycling. If the false firing stops, replace left rear sensor.

If the false firing continues, remove leads from right rear sensor and connect to left rear sensor. Drive over the same area under the same conditions that produced the false firing. If the false firing stops, replace the right rear sensor.

Step D

If all the speed sensors are functioning properly, the logic controller is faulty and must be replaced.

COMPONENT REMOVAL AND INSTALLATION

FRONT WHEEL SPEED SENSOR, Figure 12

Removal

(1) Separate the speed sensor connector in the engine compartment, and remove the sensor lead from the retaining clip.

(2) Raise the car, and remove the tire and wheel.

(3) Remove the speed sensor lead from the clamp holding it to the front wheel suspension system.

(4) Dismount the caliper. Do not disconnect hydraulic lines. Be careful to support the caliper so that the weight of the caliper is not placed on the brake hose.

(5) Remove the hub and disc assembly (the tone wheel is part of the hub and disc assembly).

(6) Remove the two bolts that secure the speed sensor to the splash shield, and the wire clip from the splash shield.

(7) Pull the speed sensor lead through the hole in the splash shield, and remove the speed sensor.

Installation

NOTE: If a new sensor is being installed, slide the sensor toward the tone wheel teeth until the plastic projections on each edge of the sensor case are against the tone wheel. The projections will wear off during the first few revolutions of the tone wheel providing the correct gap between the sensor and the tone wheel.

(1) Loosen the nut that secures the sensor to the mounting bracket, and position the sensor to provide maximum clearance between the sensor and the tone wheel.

(2) Insert the sensor lead through the hole in the splash shield, and secure the sensor mounting bracket to the splash shield with two bolts, and at-

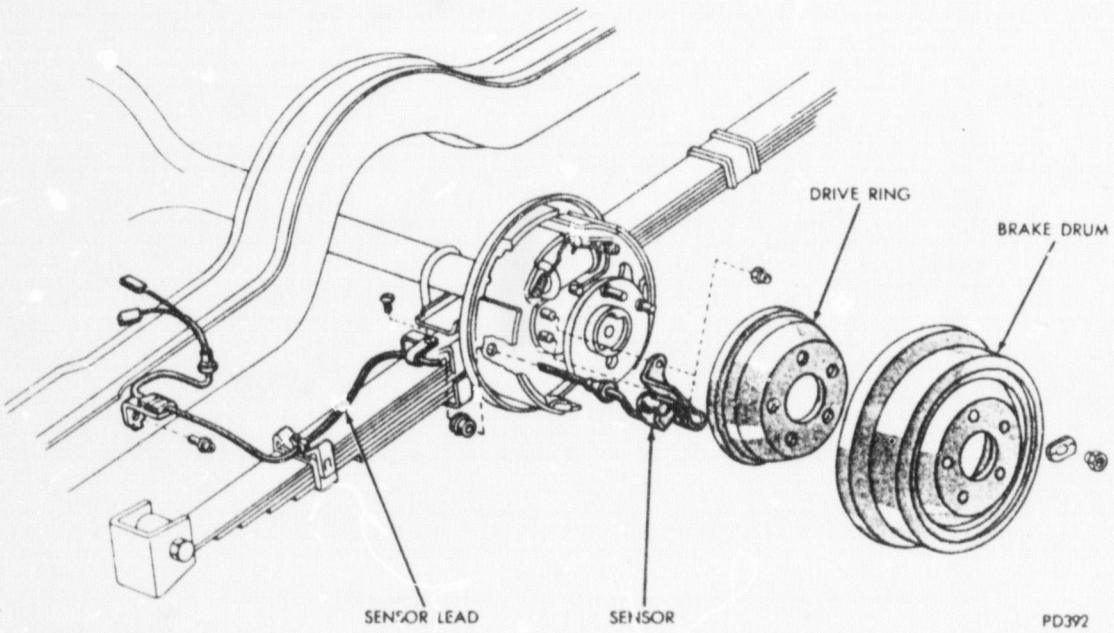

Fig. 13 - Rear Speed Sensor Mounting and Lead Routing - Left Rear Shown

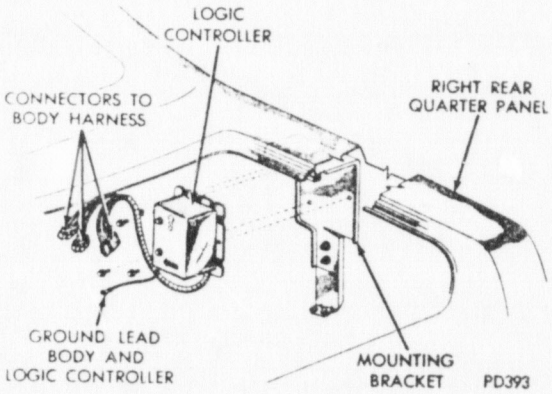

Fig. 14 - Logic Controller Mounting

tach the wire clip to the splash shield.

(3) Install the hub and disc assembly.

(4) Working through the hole in the splash shield (Figure 11), slide the sensor in the mounting bracket slot to obtain .020" clearance between the small magnets projecting from the sensor and the tone wheel teeth. If a used sensor is being reinstalled, use a narrow (1/4" wide) feeler gauge to set this clearance. Tighten the nut to **70-90** inch-pounds to secure the sensor in this position.

(5) Mount the caliper.

(6) Secure the sensor lead in the trough on the front suspension system, route the lead into the engine compartment.

(7) Install the tire and wheel and lower the car.

(8) Join the speed sensor connector in the engine compartment

REAR WHEEL SPEED SENSOR, Figure 13

Removal

(1) Separate the speed sensor connectors under the rear seat.

(2) Raise the car, and remove the tire, wheel and drum.

(3) Remove the speed sensor lead from the clamps holding it to the spring, and from the frame rail clip.

(4) Press the speed sensor toward the axle (to reduce the pressure of the knurled shaft against the drive band), and remove the drive ring.

(5) Working through the hole in the axle flange, remove the two nuts that secure the sensor and backing plate, and remove the sensor. Pull the lead through the hole in the backing plate and the floor pan.

Installation

(1) Insert the sensor lead through the hole in the backing plate.

(2) Position the sensor on the two bolts and secure with two nuts (work through the hole in the axle flange).

NOTE: Nothing should be between the speed sensor bracket and the backing plate. If necessary, the axle lock on the right wheel must be re-positioned on one of the other studs.

(3) Position the drive ring on the axle flange. Press the speed sensor toward the axle while positioning the drive ring.

(4) Assemble the sensor lead in the clamp on the spring and in the frame rail clip, and route the lead through the floor of the car. Be sure that the grommets in the car floor and backing plate are positively seated.

(5) Install the drum, tire and wheel, and lower the car.

(6) Join the speed sensor connectors under the rear seat (May be interchanged).

LOGIC CONTROLLER, Figure 14

Removal

(1) Remove the right side lining in the luggage compartment and the jack from its stowed position for access to the logic controller (LC).

(2) Disconnect the LC plugs, and remove the bolt that secures the ground wire.

(3) Remove the three screws that secure the LC to the mounting bracket and remove the LC from the car.

Installation

(1) Position the LC on the mounting bracket, and secure with three screws.

(2) Connect the LC plugs to the corresponding plugs on the body wiring harness, and **attach the ground wire securely.**

(3) Secure the jack in its stowed position and attach the side lining in place.

FRONT WHEEL PRESSURE MODULATORS (Left or Right), Figure 15

Removal

(1) Raise the hood and disconnect the modulator electrical connectors.

(2) Work down behind the turn indicator to remove the nuts that secure the modulator to the car.

(3) Raise the car, and remove the tire and wheel assembly.

(4) Remove the outer panel of the wheelhouse to permit access to the modulator.

(5) Disconnect the vacuum hose from the modulator and position the hose out of the way.

(6) Disconnect the two hydraulic lines and plug the lines to keep out dirt. Bend the lines slightly for better access to the modulator.

(7) Pull the electrical lines through the housing.

(8) Remove the two bolts that secure the side bracket to the car (Figure 16).

(9) Remove the modulator from the car.

WARNING: Do not attempt to disassemble the modulator. The heavy duty diaphragm return spring is compressed inside the modulator, and any at-

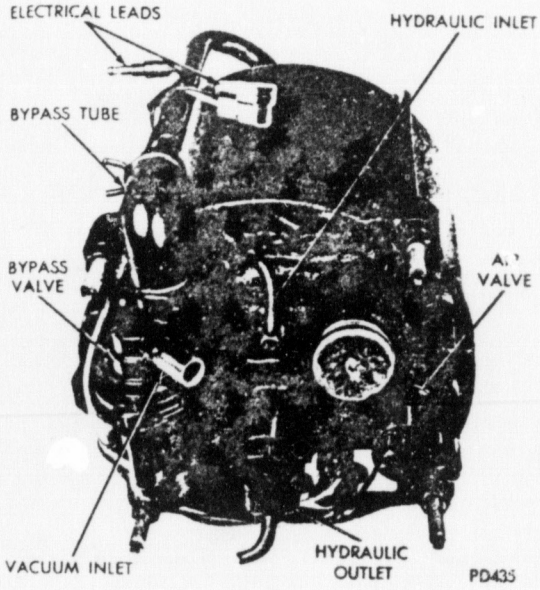

Fig. 15 - Front Modulator - Right Front Shown

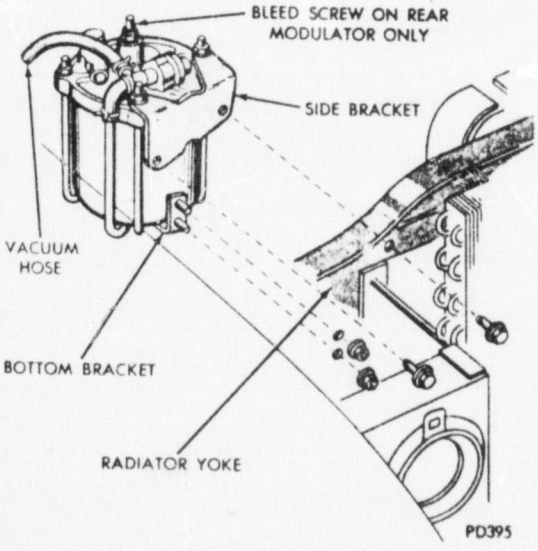

Fig. 17 - Rear Modulator Mounting Brackets

tempt to remove the "J" bolts and end plate could result in personal injury.

Installation

(1) Attach bracket to the modulator mounting bolts and nuts until all threads are started.

(2) Position the modulator in the car.

(3) Align the modulator and slide studs on end bracket through hole in panel. Start nut on each stud.

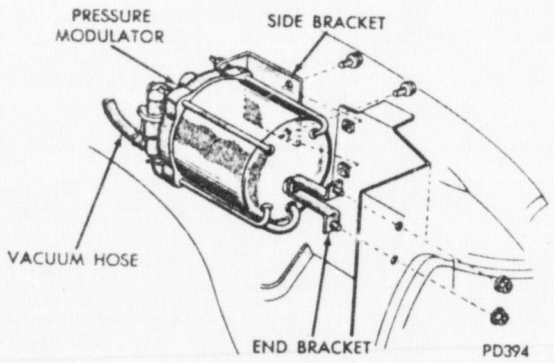

Fig. 16 - Front Modulator Mounting Brackets - Right Front Shown

(4) Secure the side bracket to the car with two bolts.

(5) Tighten all modulator mounting bolts and nuts.

(6) Route the electrical wires through the housing into the engine compartment, and connect the modulator plugs to the engine wiring harness plug.

(7) Connect the hydraulic lines to the modulator. Be sure that each line is connected to the same port from which it was disconnected.

(8) Connect the vacuum hose to the modulator.

(9) Bleed the hydraulic system to be sure that all air is removed from the system.

(10) Install the outer panel of the wheelhouse in place.

(11) Install the tire and wheel assembly, and lower the car.

(12) Make electrical and vacuum connections.

REAR MODULATOR, Figure 17

Removal

(1) Disconnect the modulator electrical connectors.

(2) Disconnect the vacuum hose from the modulator bypass valve.

(3) Disconnect the two hydraulic lines from the modulator. Plug the lines to keep dirt out of the hydraulic system.

(4) Remove the two bolts that secure the side bracket to the radiator yoke (Figure 17).

(5) Remove the two nuts that hold the bottom bracket to the radiator yoke, and remove the modulator from the car.

WARNING: Do not attempt to disassemble the modulator. The heavy duty diaphragm return spring is compressed inside the modulator, and any attempt to remove the "J" bolts and end plate could

result in personal injury.

Installation

NOTE: Do not tighten the modulator mounting bolts and nuts until all threads are started.

(1) Position the side bracket on the modulator, and secure with two nuts and lockwashers.

(2) Position the modulator in place, and secure the bottom bracket to the radiator yoke with two nuts.

(3) Install the two bolts that secure the side bracket to the radiator yoke.

(4) Tighten all modulator mounting bolts and nuts.

(5) Connect the hydraulic lines to the modulator. Be sure that each tube is connected to the same port from which it was disconnected.

(6) Connect the vacuum hose to the modulator bypass valve.

(7) Connect the modulator electrical plugs to the

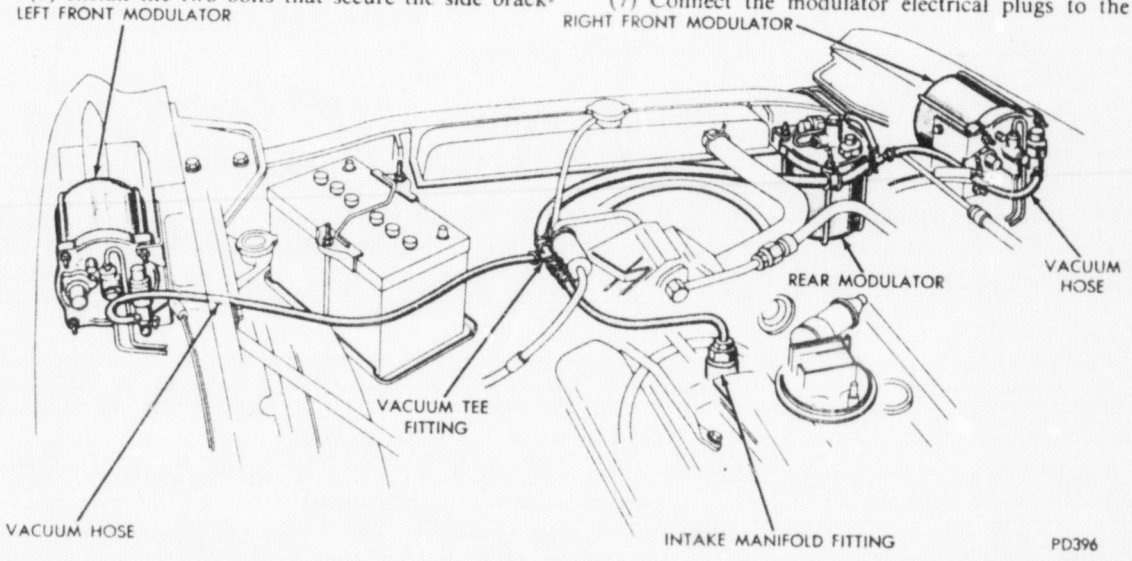

Fig. 18 - Vacuum Hose Routing

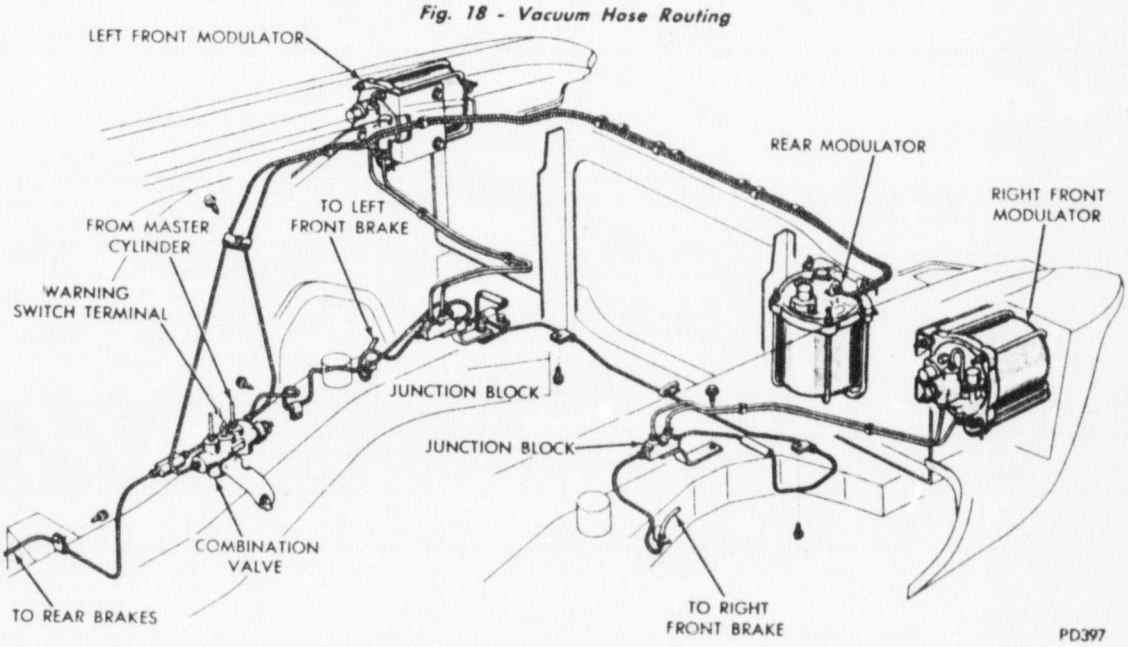

Fig. 19 - Hydraulic Tube Routing

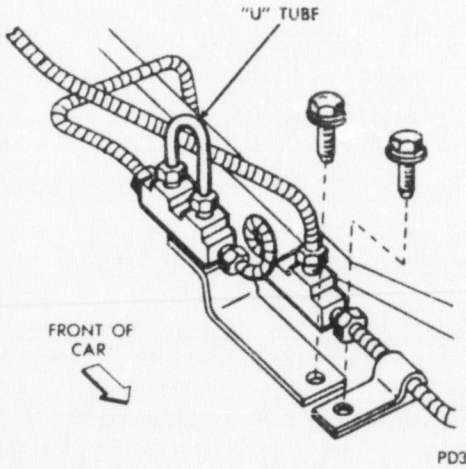

Fig. 20 - "U" Tube in Front Brake Line

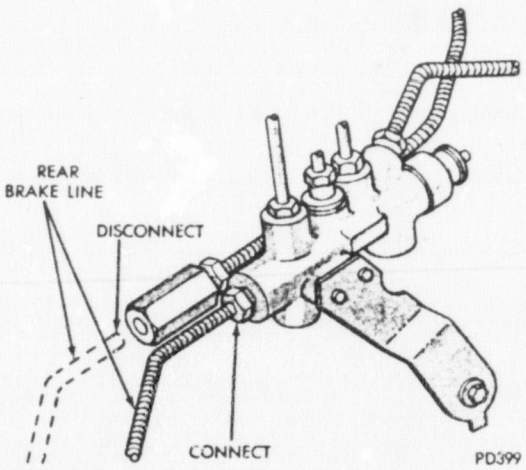

Fig. 21 - Re-route Rear Brake Line

engine wiring harness plug.

(8) Bleed the hydraulic system to be sure that all air is removed from the system. After bleeding at the wheel cylinders, the modulator hydraulic cylinder must be bled at the bleed screw located on the modulator.

DISABLING THE SURE BRAKE SYSTEM

If necessary parts are not available or for some other reason the Sure Brake System cannot be repaired, the system should be disabled. The brakes then will function the same as those on cars without the Sure Brake System, and the car can be operated safely.

For most of the failures that can possibly occur, the system can be completely disabled by disconnecting the logic controller (all three connectors) (Figure 14) and the vacuum supply hose. The vacuum hose should be separated at the "T" connection (Refer to Figure 18) leading to the modulator. The line to the intake manifold should be plugged. The line to the modulators should be taped to keep out any dirt.

An **additional step is necessary** to disable the system for one type of failure that can possibly occur. This is a failure that causes the pressure modulator diaphragm plate to stick in the retracted or partially retracted position.

If a diaphragm plate sticks in the retracted position, the hydraulic cut off valve in the modulator remains closed. Thus, hydraulic pressure is cut off from the brake (both brakes if rear modulator) that is connected to the modulator.

To assure that the basic brake system is not affected by a hydraulic restriction; place car on hoist, spin wheels by hand to insure that wheels are free. With brakes applied attempt to spin wheels, release brakes and spin wheels again, if a wheel spins with the brakes applied or does not rotate with brakes released, the modulator for that wheel must be bypassed. Modulators can be bypassed by performing the following: **front** modulators, a "U" tube should be placed in the system after the modulator tubes have been removed (see Figures 18, 19 and 20). **Rear** modulator, route the brake line from the rear wheels directly into the rear of safety tee after modulator line has been disconnected (see Figures 18, 19 and 21). Fittings shown in Figures 18, 19, 20 and 21 are located in the engine compartment.

On the rear modulator, both hydraulic tubes should be disconnected at the combination brake warning/proportioning metering valve. This completely bypasses the modulator for the rear brakes.

The changes in the hydraulic connections are in addition to disconnecting the vacuum and electrical supply from the system as noted above.

Road test the car and check braking action after disabling the system.

5-80 SPECIFICATIONS

VALIANT MODELS	6 Cyl.	6 Cyl. H.D. & V-8
Type	Duo-Servo Single Anchor	Duo-Servo Single Anchor
DRUM DIAMETER	9"	10"
NUMBER OF BRAKE SHOES	8	8
BRAKE LINING	Extruded and Molded Asbestos-Bonded	Extruded and Molded Asbestos-Bonded
WIDTH		
Front	Pri. 2-1/4" Sec. 2-1/2"	2-1/4"
Rear	2"	1-3/4"
LENGTH		
Front Primary	7-5/8"	8-1/2"
Front Secondary	9-5/8"	11"
Rear Primary	7-5/8"	8-1/2"
Rear Secondary	9-5/8"	11"
THICKNESS		
Primary	3/16"	3/16"
Secondary	1/4"	1/4"
WHEEL CYLINDER	4 per car	4 per car
Front Wheel Cylinder Bore	1"	1-3/16"
Rear Wheel Cylinder Bore	13/16"	15/16"
MASTER CYLINDER BORE	15/16"	1-1/32"

SATELLITE and BARRACUDA MODELS	6 Cyl.	V-8 & H.D. & Sub.
Type	Duo-Servo Single Anchor	Duo-Servo Single Anchor
DRUM DIAMETER	10"	10"
(Heavy Duty)	11"	11"
NUMBER OF BRAKE SHOES	8	8
WIDTH (Standard)		
Front	2-1/2"	2-1/2"
Rear	2-1/2"	2-1/2"
(HEAVY DUTY)		
Front	3"	3"
Rear	2-1/2"	2-1/2"
BRAKE LINING (10-INCH)	Extruded Asbestos-Bonded	Extruded Asbestos-Bonded
LENGTH		
Front Primary	8-1/2"	8-1/2"
Front Secondary	11"	11"
Rear Primary	8-1/2"	8-1/2"
Rear Secondary	11"	11"
BRAKE LINING (11 INCH HEAVY DUTY)		
LENGTH		
Front Primary	9-1/4"	9-1/4"
Front Secondary	12-1/8"	12-1/8"
Rear Primary	9-1/4"	9-1/4"
Rear Secondary	12-1/8"	12-1/8"
Thickness Primary	3/16"	3/16"
Secondary	1/4"	1/4"
WHEEL CYLINDER		
Front Wheel Cylinder Bore	1-3/16"	1-3/16"
Rear Wheel Cylinder Bore	15/16"	15/16"
MASTER CYLINDER BORE	1-1/32"	1-1/32"

FURY MODELS	
TYPE	Duo-Servo Single Anchor
DRUM DIAMETER	11 in.
(Police & Heavy Duty)	11 in.
NUMBER OF BRAKE SHOES	8 in.
WIDTH	
Front (Up to, including 360 Cu. In. Engine)	2-3/4 in.
Rear (Automatic Transmission)	2 in.
(Manual Transmission)	2-1/2 in.
(HEAVY DUTY)	
Front	3 in.
Rear	2-1/2 in.
Station Wagon (Front)	Disc
Station Wagon (Rear)	2-1/2 in.
BRAKE LINING	Extruded and Moulded Asbestos-Bonded
LENGTHS	
Front Primary	9-1/4 in.
Front Secondary	12-1/8 in.
Rear Primary	9-1/4 in.
Rear Secondary	12-1/8 in.
(HEAVY DUTY)	
Front Primary	9-1/4 in.
Front Secondary	12-1/8 in.
Rear Primary	9-1/4 in.
Rear Secondary	12-1/8 in.
Thickness – Secondary	1/4 in.
Thickness – Primary	3/16 in.
WHEEL CYLINDER	
Front Wheel Cylinder Bore (Drum)	1-3/16 in.
(Disc)	2-3/4 in.
Rear Wheel Cylinder Bore (Including Disc Brake Equipped Vehicles)	15/16 in.
MASTER CYLINDER BORE (Drum or Disc)	1-1/32 in.

CHRYSLER-IMPERIAL MODELS	Chrysler	Imperial
TYPE	Duo-Servo Single Anchor	
DRUM DIAMETER	11 in.	
(Heavy Duty)	11 in.	
NUMBER OF BRAKE SHOES	8	4
WIDTH		
Front	Disc	Disc
Rear	2-1/2 in.	3 in.
(Heavy Duty Including Station Wagon)		
Front	Disc	
Rear	2-1/2 in.	
BRAKE LINING	Extruded and Moulded Asbestos-Bonded	
LENGTH		
Rear Primary	9-1/4"	
Rear Secondary	12-1/8"	
WHEEL CYLINDER		
Front Wheel Cylinder Bore (Disc)	2-3/4"	
Rear Wheel Cylinder Bore	15/16"	
MASTER CYLINDER BORE (Drum or Disc)	1-1/32"	

5-82 SPECIFICATIONS

VALIANT

Type of Brake	Fixed Caliper Disc
Location	Front Wheels Only
Master Cylinder Reservoir	Horizontal Tandem (Dual)
Proportioning Valve Location	Left Sill (Brake Warning Switch Assembly)
Brake Adjustment	None (Automatic)
Residual Valve Location	In Master Cylinder Outlet (to rear brakes only

CALIPER ASSEMBLY

Shoe and Lining Removal	Radially Outward (Remove Clips)
Number of Pistons	4 (Each Unit)
Piston Diameter	1-5/8"
Piston Bore Diameter	1.636"
Maximum Allowable (After Honing)	1.638"
Piston Seals	Moulded Rubber (Square Section .092" Wide, .100" Radial Thickness
Piston Dust Boots	External Moulded Rubber 4 Per Unit
Bleeder Screw Location	Outer Housing 3/8"
Transfer Tube Type	Short Overhead

BRAKING DISC

Type	Ventilated Cast Iron
Diameter Outside	11.04"
Inside	6.91"
Disc Runout (Maximum Allowable) T.I.R.	.0025"
Disc Surface Finish	15 to 80 Micro Inches
Disc Thickness	.810"
Disc Parallelism (Total Variation in Thickness)	.0005"

BRAKE SHOE AND LINING

Type	Bonded
Lining Thickness	.400" (Nominal)
Width	1.84"
Length	4.82"
Braking Area	8.50" Sq. In./Segment
Maximum Wear (Minimum Thickness Allowed)	Not less than 1/32" lining at any point or a minimum shoe and lining thickness of .180"

MASTER CYLINDER

Piston Bore Diameter	1-1/32"
Maximum Bore Diameter Allowable (After Honing)	.002" o.s.
Residual Valve	Rear Brakes Only

DISC SPLASH SHIELD

Type	Vented Stamped Steel
Mounting	3 Bolts to Knuckle

PROPORTIONING VALVE

Type	Pressure Control
P.S.I.	300 P.S.I.
Reduction in Rate of Rear Line Pressure Build Up	After 300 P.S.I. Actuation Pressure

IMPERIAL CHRYSLER FURY SATELLITE BARRACUDA

Type of Brake	Floating Caliper
Location	Front Wheels Only
Master Cylinder	Horizontal Tandem (Dual)
Metering Valve Location	Below Master Cylinder, Combined with Brake Warning /Proportioning Valve
Proportioning Valve (Satellite, Barracuda, Fury, Imperial (Except Suburban)	Below Master Cylinder, Combined with Brake Warning/ Metering Valve
Brake Adjustment	None Required
Residual Valve Location (Rear Brakes Only)	In Master Cylinder Outlet
CALIPER ASSEMBLY	
Shoe and Lining Removal	Bottom, Caliper Removed
Number of Pistons	1 Each Unit
Piston Diameter	2-3/4" (2.751"-2.753")
Piston Bore Diameter Maximum Allowable (After Honing)	2.757"
Piston Seal	Moulded Rubber (Square Section) .126" Wide—120" Radial Thickness
Dust Boot	Moulded Rubber (External) 1 Per Unit
Bleeder Screw Location	Inner Housing 3/8"
BRAKING DISC	
Type	Ventilated Cast Iron
Diameter (Outside)	
Fury-Chrysler-Imperial Models	11.75"
Satellite—Barracuda Models	10.98"
Diameter (Inside)	
Fury—Chrysler—Imperial Models	7.725"
Satellite—Barracuda Models	6.98"
Disc Run-out (Maximum Allowable) T.I.R.	.0025"
Disc Surface Finish	15 to 80 Micro Inches
Disc Thickness	
Fury—Chrysler—Imperial Models	1.250-1.240
Satellite—Barracuda Models	1.000-1.010
Disc Parallelism (Total Variation in Thickness)	.0005"
BRAKE SHOE AND LINING	
Type	Bonded
Lining Thickness	.400" (Nominal)
Wide	1.80" (At Center)
Long	6.02"
Braking Area	10.0" (Square inches per pad)
Maximum Wear (Minimum Thickness Allowed	Not less than .030" lining at any point or a minimum shoe and lining thickness of .230 Inch
MASTER CYLINDER	
Piston Bore Diameter	1-1/32"
Maximum Bore Diameter Allowable (After Honing)	.002" O.S.
Residual Valve	Rear Brakes Only
DISC SPLASH SHIELD	
Type	Vented-Stamped Steel
Mounting	3 Bolts to Knuckle

TIGHTENING REFERENCE

	Foot Pounds	Inch Pounds
HYDRAULIC BRAKE LINES		
Brake Line Tube Nuts, 3/8 or 7/16		80-150
1/2 or 9/16		125-175
Flexible Brake Hose		
To Brake Line Tubes (All)		80-150
To Brake "T" (Rear)		200
To Wheel Cylinders (All)	25	
MASTER CYLINDER		
Master Cylinder to Dash Panel or Booster front cover		80-200
Master Cylinder Pedal Link Bolt	30	
POWER BRAKE		
Power Brake Assembly to Dash		150-220
Power Brake Brace and Support Nuts (Small Tandem Diaphragm)		100 - 200
Lower Pivot Certain Models, See Text	29	
WHEEL CYLINDERS		
Wheel Cylinder to Support Plate 9" Brake		110
Wheel Cylinder to Support Plate 10" and 11" Brake		220
BRAKE SUPPORT PLATE		
Front (To Steering Knuckle)		
Except Valiant, Top attaching bolts	55	
Bottom attaching bolts	120	
Valiant, Top attaching bolts	55	
Bottom attaching bolts	100	
Rear (To Axle Flange)		
All	35	
WHEEL BEARING NUT		
All except Valiant (Wheel rotating)		90
Valiant (Wheel rotating)		70
WHEEL STUD NUTS		
All except Valiant	65	
Valiant	55	
DISC BRAKE (FIXED CALIPER)		
Caliper Mounting Bolts	50-80	
Caliper Assembly Bridge Bolts	70-80	
Disc Splash Shield Bolts		220
Caliper Bleeder Screw		100
Shoe Clips (Retainers)	7-9	
Proportioning Valve to Frame Screw		180
DISC BRAKE (FLOATING CALIPER)		
Adapter Mounting Bolts	75-100	
Guide Pins	25 - 35	
Disc Splash Shield Screws		220
Proportioning Metering Valve Assembly to Frame Screw		200

BRAKE EQUIPMENT APPLICATION CHART

MODELS	FRONT DISC OR DRUM SIZE	REAR DRUM SIZE	CONTROL SWITCH/VALVES	ACTUATION
VALIANT				
All 6 Cyl. Except Manual Trans. with Sure-Grip	9x2-1/2	9x2	Brake Warning Switch	Manual Power
All 6 Cyl. with Sure-Grip and Manual Trans./All 8 Cyl.	10x2-1/4	10x1-3/4	Brake Warning Switch	Manual-Power Opt.
Optional All	Disc	10x1-3/4	Brake Warning/Proportioning Assembly	Opt. Power
BARRACUDA				
All	10x2-1/2	10x2-1/2	Brake Warning Switch	Manual Only
Optional All	Disc	10x2-1/2	Brake Warning/Proportioning /Metering Assembly	Power Only
SATELLITE (Except Suburban)				
All with 225, 318, 400 2BBL or 400 4BBL Engines (Except Police Models or Road Runner)	10x2-1/2	10x2-1/2	Brake Warning Switch	Manual Only
Optional, All Above-Standard with 440 Engine, Taxi, Police Models	11x3	11x2-1/2	Brake Warning Switch	Manual Only
Optional All, Except Police, Taxi. Not Available 3.54, 3.55, 3.91, 4.10 Axle Ratio	Disc	10x2-1/2	Brake Warning/Proportioning /Metering Assembly	Power Only
Optional All Standard with Trailer Tow	Disc	11x2-1/2	Brake Warning/Proportioning /Metering Assembly	Power Only
SATELLITE SUBURBAN-ALL	11x3	11x2-1/2	Brake Warning Switch	Manual Only
Optional	Disc	11x2-1/2	Brake Warning/Metering Assembly	Power Only
FURY (Except Suburban)				
All 318, 360, 400 2BBL Engine	11x2-3/4	11x2	Brake Warning Switch	Manual Only
All 400 4BBL, 440 Std. Engine Note: All Models 400 2BBL and Sure Grip	11x2-3/4	11x2-1/2	Brake Warning Switch	Manual Only
Police, Except 440 H.P., Taxi	11x3	11x2-1/2	Brake Warning Switch	Manual Only
Optional with 318, 360 and 400 2BBL Engine	Disc	11x2	Brake Warning/Proportioning /Metering Assembly	Power Only
Standard with Trailer Tow, 440 H.P. Engine Optional, Police, Taxi, 400 4BBL and 440 Std. Engine. Note: All Models with 400 2BBL Engine and Sure-Grip	Disc	11x2-1/2	Brake Warning/Proportioning /Metering Assembly	Power Only
FURY SUBURBAN				
With 318, 360 Engine	11x3	11x2-1/2	Brake Warning Switch	Manual Only
With 400 2BBL, 400 4BB' Engine Optional with 318, 360 Engine	Disc	11x2-1/2	Brake Warning/Metering Assembly	Power Only
CHRYSLER (Except Suburbans)	Disc	11 x 2-1/2	Brake Warning/Proportioning /Metering Assembly	Power Only
CHRYSLER SUBURBAN	Disc	11 x 2-1/2	Brake Warning/Metering Assembly	Power Only
IMPERIAL (and Sure Brake)	Disc	11 x 3	Brake Warning/Proportioning /Metering Assembly	Power Only